THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

THE INSTITUTION OF

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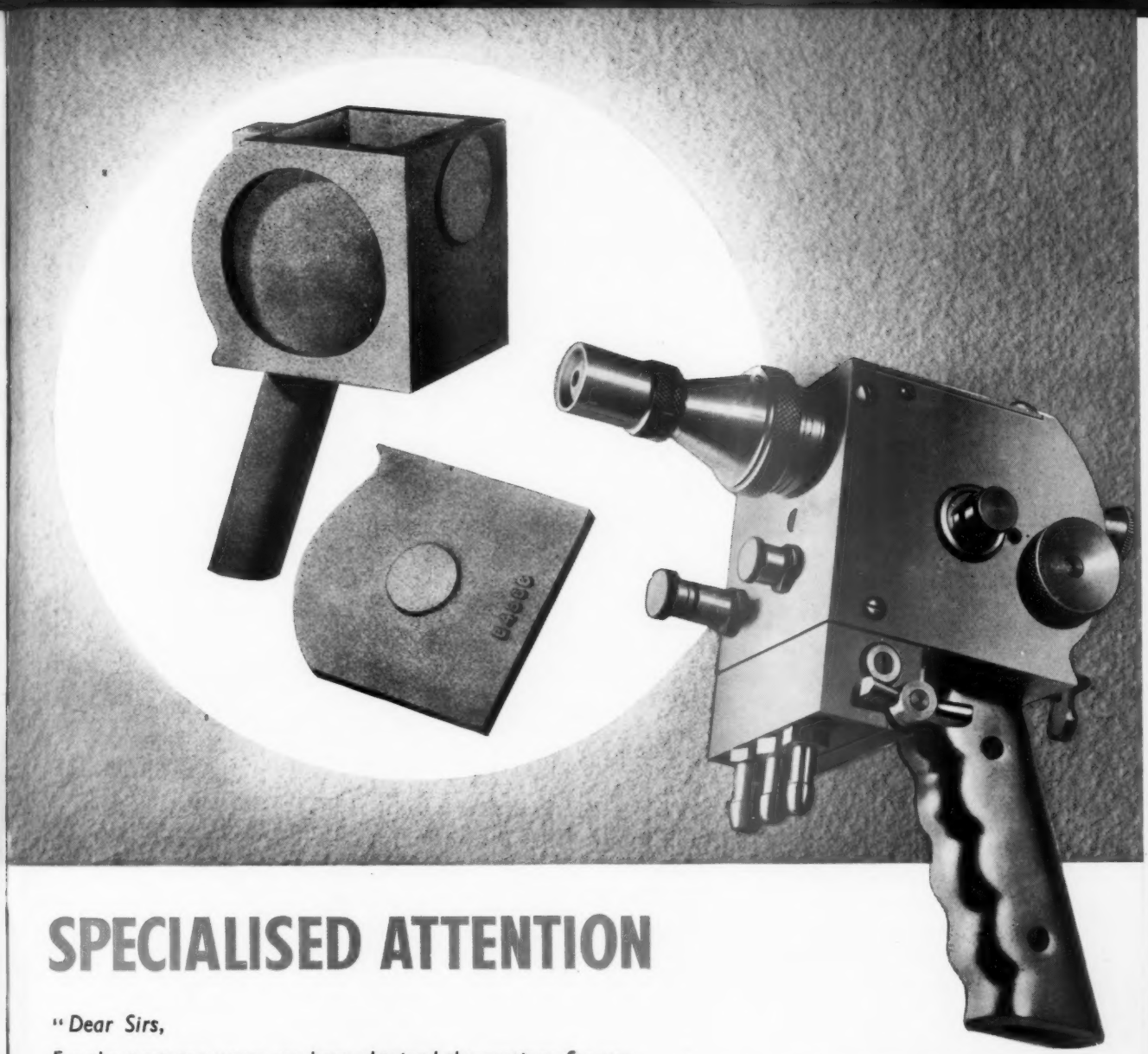

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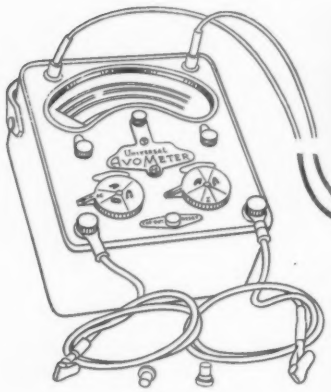

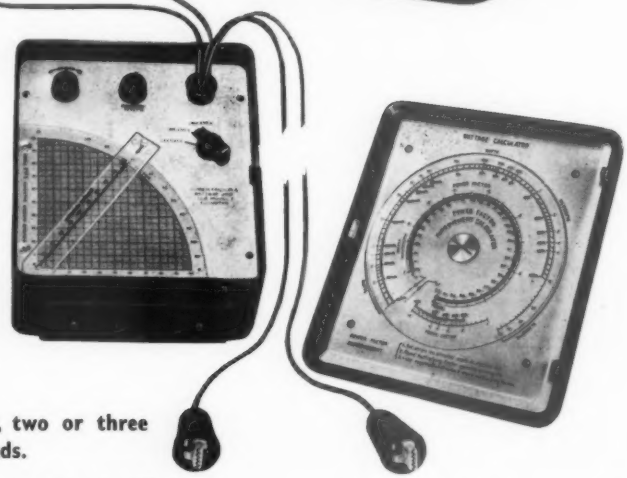

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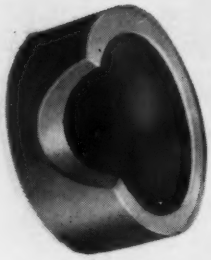

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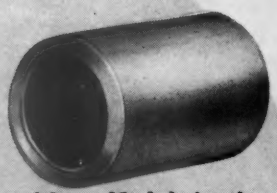

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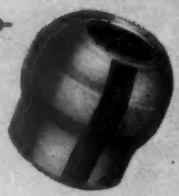

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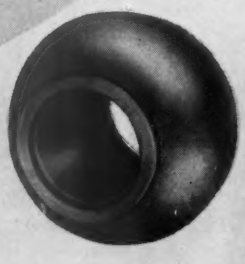

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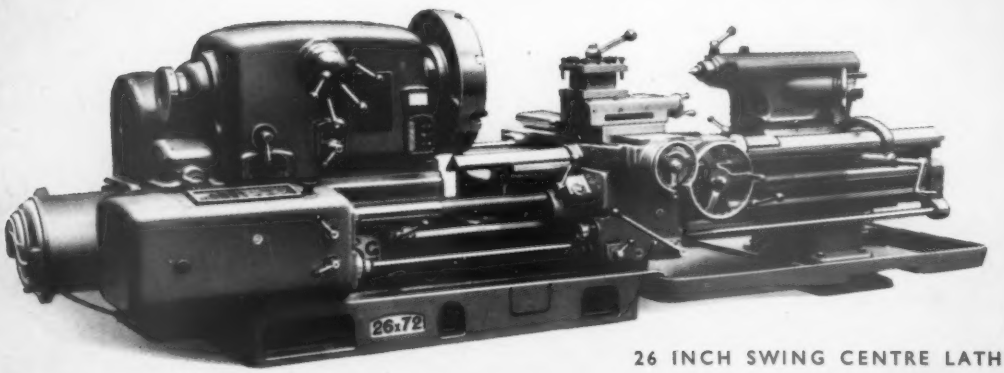

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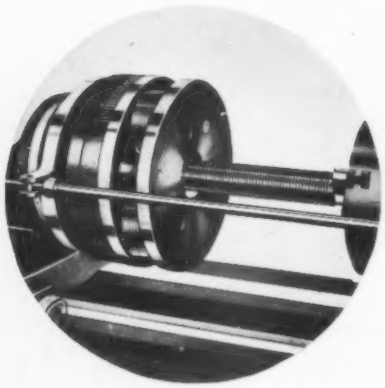

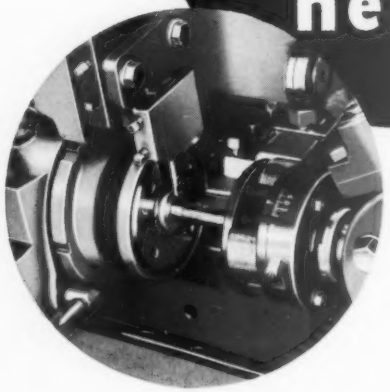

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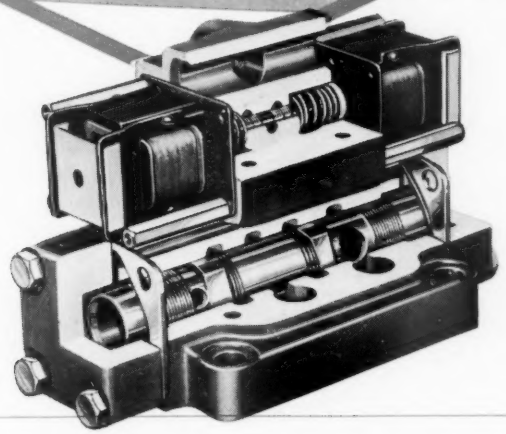

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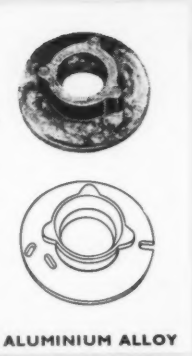

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2nd op. 21 seconds
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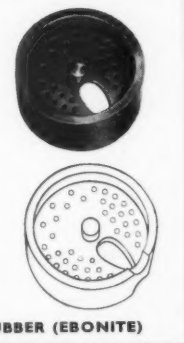

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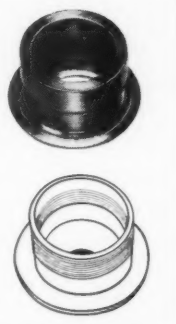
Machining time : 28 seconds



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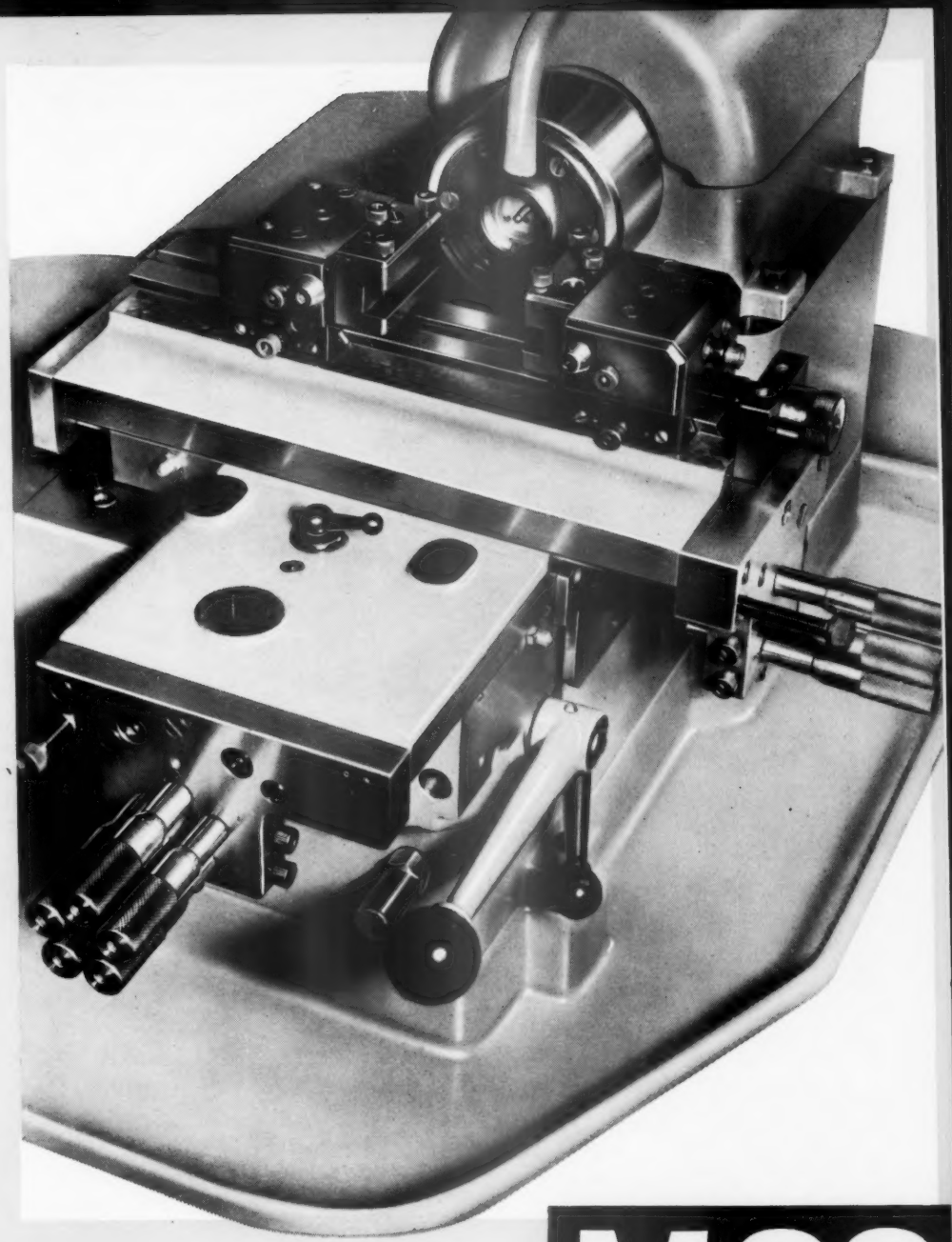
Machining time : 1st op. 15 seconds
2nd op. 13 seconds



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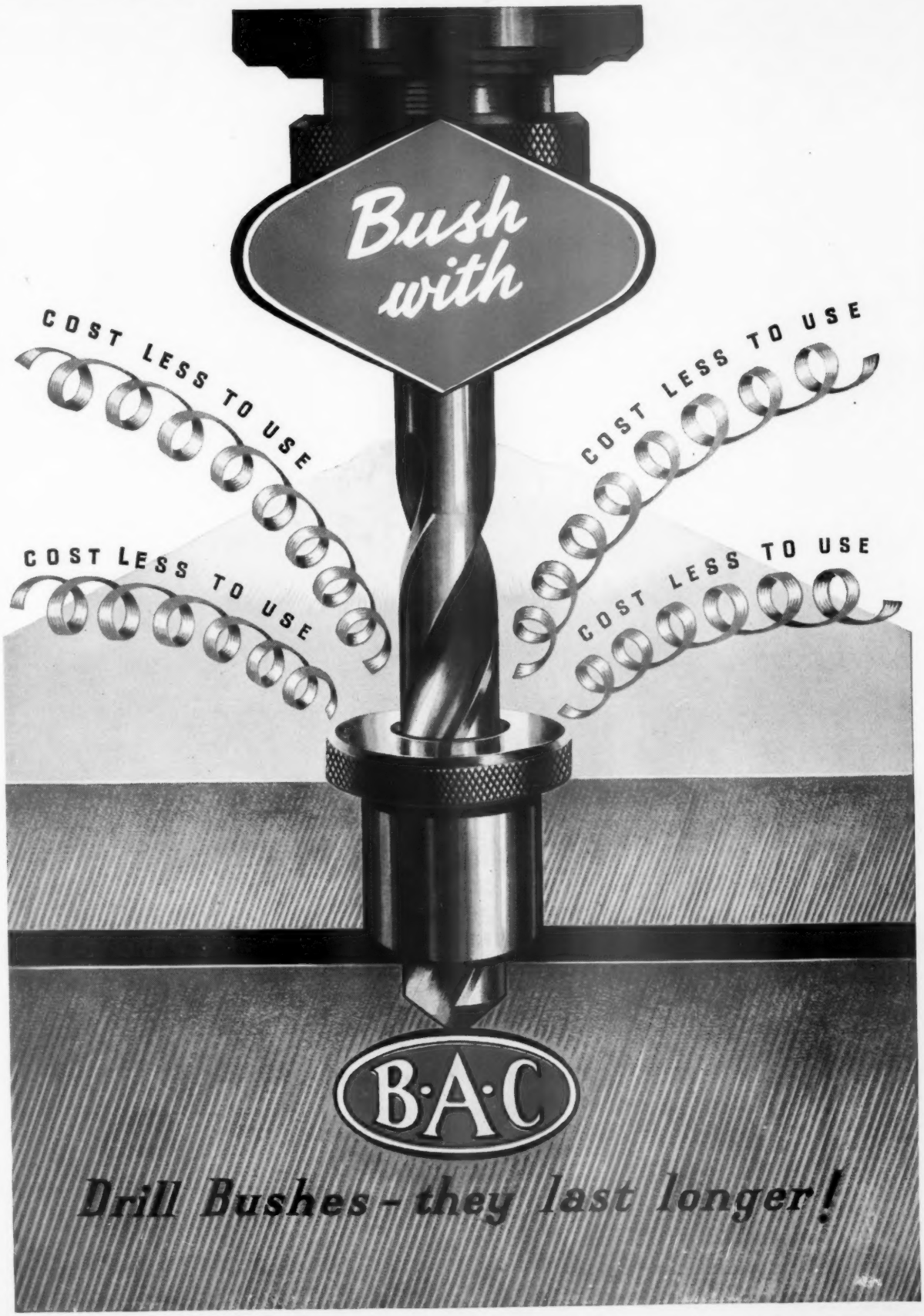

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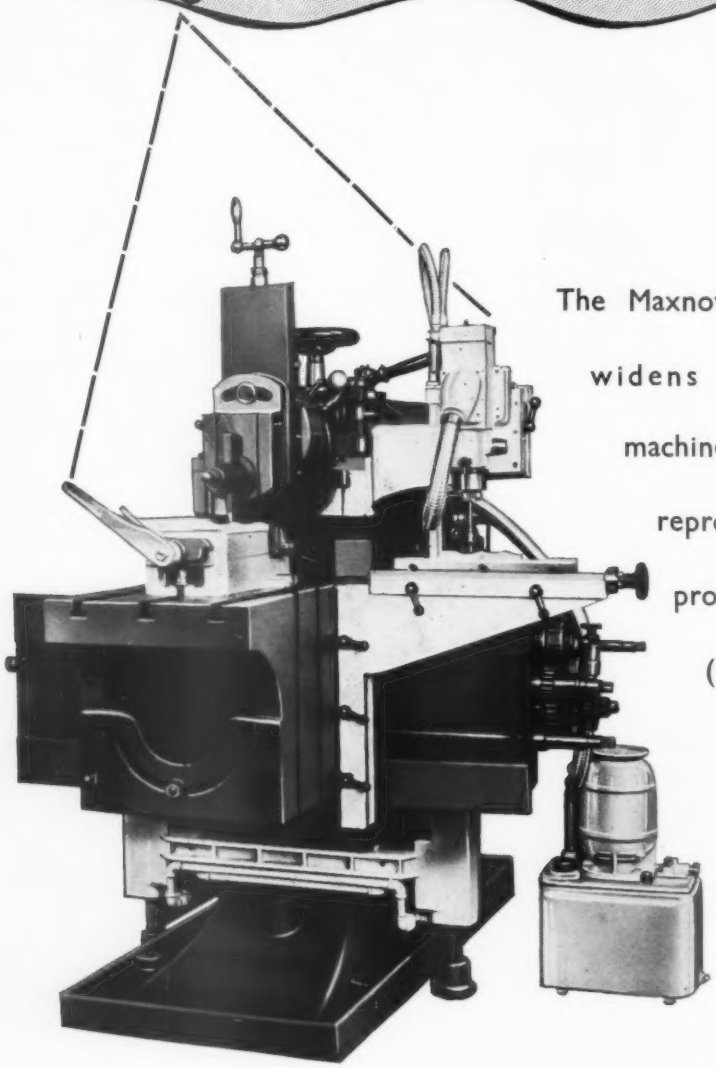

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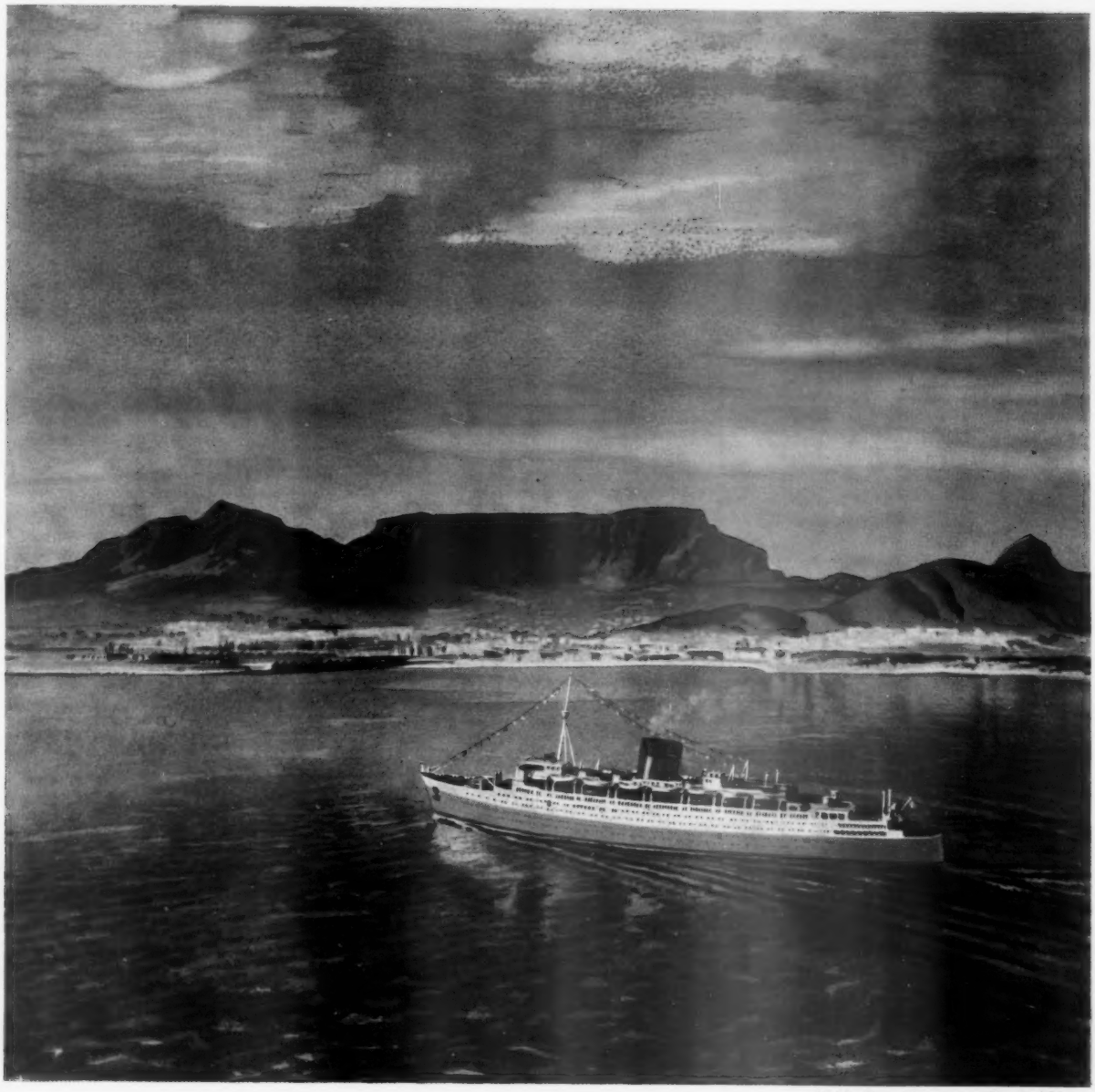

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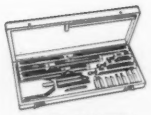

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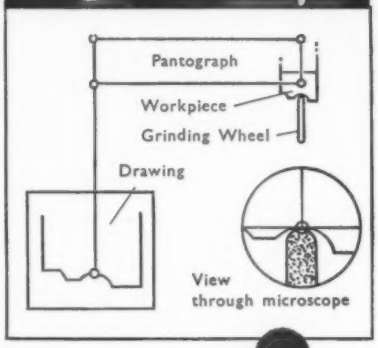

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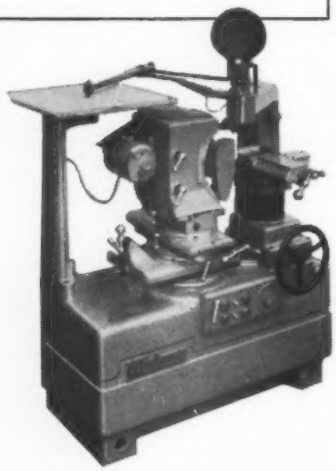

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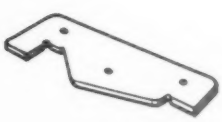

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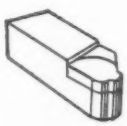

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The Institution of Production Engineers Journal
VOL 33. NO. 4 APRIL, 1954

The Finance of Production

by S. P. CHAMBERS, C.B., C.I.E.,
Deputy Chairman, Imperial Chemical Industries, Ltd.

PRODUCTIVITY depends upon many factors. However well-managed a business may be productivity will be at a low level if, because of a shortage of raw materials or of markets for the product, the total output is limited to a small proportion of capacity. Leaving aside external factors of this kind, however, the three main internal factors upon which productivity depends are (a) labour. with the necessary skill and incentives, (b) management—also with the necessary skill and incentives, and (c) capital.

Factor (a) receives a good deal of publicity and it is quite proper that much thought and effort should be devoted to methods of increasing both the skill of the labour force, and the incentives which they are given to bring out their best work. For many enterprises factor (b) may be more important than factor (a). In such businesses improved management can make more difference to productivity than improvement in the skill and the application to work of pay-roll employees. It is being recognised, rather belatedly perhaps, that management also needs incentives.

But we are concerned in this article mainly with the third factor. In a well-organised business, if workers and management at all levels have the necessary skill and incentives, the greatest increase in productivity can come from improvements in factor (c), i.e. the capital equipment at the disposal of management and workers.

There are many cases in which by the application of improved methods and work study, output has been put up to a remarkable extent, but where the output per head could be much higher still if modern methods and modern machinery were installed.

If a comparison is made between British industry and American industry, it will be found that the amount of capital per head in American industry is on average more than twice that in British industry. The greater productivity per head in the United States is probably due more to this factor than to any other. With high rates of pay American management is constantly on the search for means of achieving higher production with less labour. Most labour-saving devices mean more capital. In some cases a revolution in methods of production can save more than half the labour force, but the price to be paid is more capital.

It does not follow that with more capital, output per head goes up automatically. Indeed, there are examples in British industry of restrictive practices which discourage the best use of modern capital equipment. Efforts to improve productivity through factors (a) and (b)—labour and management—must not be relaxed in the belief that with better equipment higher productivity will come automatically.

The word "capital" is used in several different senses, and there is a good deal of misunderstanding about the nature of real capital. Real capital consists of the buildings, plant, machinery, stocks and work in progress which are necessary to any manufacturing enterprise. To provide this capital equipment, the proprietors must, of course, put up the necessary money capital, although some part of it may be provided from loans, bank overdrafts, and even unpaid creditors.

Real capital in the sense in which we are using this expression is necessary whatever the social or political environment in which the industry operates. It is necessary whether we have a capitalist society, a socialist society, or even a communist society. The differences which these different political conditions make are mainly in the ownership of the capital—the need for the capital is the same in all cases.

If we now ask the question, where does the money come from to provide the capital, the answer is that it can come only from savings. Apart from capital imported from overseas, the amount of capital available to the trade and industry of any country can grow only to the extent that production exceeds consumption. It does not follow that if production exceeds consumption, capital will *always* be formed. If the finances of a country are in a bad condition, the excess of production over consumption may not emerge as capital, but as over-production, leading to unemployment, which, on any appreciable scale, is the worst possible misuse of the country's resources of manpower. If, however, the country's finances are wisely controlled, there should be a moderate excess of production over consumption, which on the one hand emerges as savings out of income and, on the other, as additional capital equipment.

For the community as a whole, there are other demands on capital which compete with industry. These consist mainly of private capital (houses, and other durable personal possessions) and Government capital (war-ships, aeroplanes, Government buildings, etc.). In practice industry gets only a modest proportion of the total capital available in any year. For example, in 1952, out of a total investment on fixed capital equipment of £m2,000, manufacturing industry took only £m625; the largest other users of capital were, new housing £m430; electricity, gas and water £m245; transport and communications £m245; and social services and administration £m135.*

If more capital is taken by these other users of capital, less is available for manufacturing industry, and in recent years the restriction on capital expenditure in industry has perhaps been rather more effective than the restriction on other users of capital. The result has been that British industry has been starved of capital by comparison with American industry, although it is fair to say that from 1952 onwards there has been an improvement.

The savings which are the source of capital can be analysed between (a) individual saving, (b) corporate saving, and (c) Government saving.

In the 19th Century and in the first quarter of the 20th Century private savings were confined almost entirely to the middle and upper income groups. Since then the increased scale of direct and indirect taxation has cut away the surplus income which individuals with moderate or large incomes had available for saving. There has been no increase in saving in the lower income groups. As a consequence individual saving has almost disappeared. It is true that the Government figures show the figure for saving and provisions for depreciation and stock appreciation by persons (excluding companies) as £m341, but it is probable that the depreciation provisions alone count for a substantial part of this figure. This figure also covers all personal savings made indirectly through insurance companies and pension funds, and there is no doubt that this method of saving accounts for practically the whole of the personal saving done by individuals today. Indeed, it is probable that *direct* savings by individuals are a minus quantity, i.e. the amount spent out of capital by individuals exceeds the amount of saving. The reason for the concentration of personal savings in this way through insurance companies and pension funds is that this form of saving is the subject of special tax reliefs. Thus the very steep graduation of taxes, accompanied by reliefs for particular forms of saving, has resulted in a distortion of the channels of savings.

One objection to this distortion is that the form of the savings is now less satisfactory for industry, and is particularly unsatisfactory for the small private business. In the 19th Century much of British industry depended upon the personal skill of individuals, backed by their own direct savings, and by the savings of those who knew and trusted them. The savings which are made through insurance companies and pension funds are not available in this direct way to small businesses.

Saving by companies takes place, of course, by a policy of distributing less than the full profit made in any year. Each successive Chancellor of the Exchequer has urged Boards of Directors to exercise a policy of moderation and restraint in paying dividends. This pressure has been exerted for two reasons, one being a psychological one (the theory being that such a policy may induce pay-roll workers to moderate their demands for wage increases) and the other being the desire to see a restraint upon consumption, and the building up of capital resources for industry.

The amount shown for company savings in the Government statistics** for 1952—£m1170—seems impressive, but the true figure of savings is much smaller.

* Economic Survey for 1953 — CMD.8800.

** National Income and Expenditure 1952, published by H.M. Stationery Office in August, 1952.

This figure includes the provisions for depreciation of fixed assets. The amount of annual depreciation provision necessary for the replacement of industry's plant and equipment calculated at today's construction costs is of the order of between £m600 and £m700, so that true savings must be very small.

Government savings represent the excess of the amounts collected by taxation over the amounts spent. In theory, local Governments can save just as a central Government can, by collecting more in rates and taxes than they spend, but their expenditure is itself so high that this is little more than a theoretical possibility. One Chancellor of the Exchequer expressed the opinion that if savings by individuals and companies were insufficient to provide all the capital needed, both by industry and by the Government for its own purposes, then the Government itself must step in and make substantial savings by putting up taxes substantially in excess of Government expenditure. If such a course were followed, then gradually a growing proportion of capital would be owned by the Government, and this could hardly do other than lead, in the long run, to a totalitarian state, in which most of industry was owned by the State.

British industry needs more capital, but the sources from which it gets the capital must be carefully watched. Individual savings need encouragement, and this can only be done by some form of tax reduction. Savings by companies are at the present time severely limited by the effect of the profits tax, which is charged over and above income tax. Here again it is better that the savings needed by businesses, particularly the smaller businesses, should come, as far as possible, from the proprietors themselves, and this also needs encouragement by tax reductions.

Tax reductions which are not accompanied by reductions in Government expenditure can be inflationary, and in the long run this can do still more damage in eating away real capital, but the problem which faces this country, and indeed all other countries, is to find some means of making Government expenditure a smaller proportion of national income, without cutting seriously into the expenditure on defence and social services.

There is one way in which, without cutting Government expenditure very much, it can become a smaller proportion of the national product, and that is to increase productivity. In this way the amount spent by the Government may remain unchanged, but because of greater productivity and higher standards of living, this amount may become a lighter burden. So we see here the full circle from productivity to national income and Government expenditure, each of which reacts upon the other. If productivity were higher, taxes could be lower without reducing the amount of resources available for Government expenditure. On the other hand, if taxes were lower, more capital would be available for industry, and productivity could be increased. The vicious circle downwards would be higher taxes and lower productivity, which makes necessary still higher rates of taxation to produce the same resources needed to cover the country's defence and social service requirements. The circle upwards is higher productivity and lower taxation, but this can only be a gradual process. The best hope for Britain at the present time lies probably in still greater concentration upon factors (a) and (b), with which we started, labour and management. If by improved methods of work and improved incentives we push up productivity without requiring any material increase in the capital needed, we make a very direct contribution towards solving the country's problems of financing defence and social services on a reducing instead of an increasing burden of taxation.

COUNCIL ELECTIONS 1954/55

At the Annual General Meeting of the Institution held on Thursday, 28th January, 1954, the new Articles of Association were adopted. There are certain constitutional changes arising from the adoption of these Articles, and this notice is to draw your attention to a particular change in respect of elected members on Council. Under the new Articles there will be vacancies for 16 full Members and 2 Associate Members. A notice calling for nominations for an election to fill these vacancies will be published in the May issue of the Journal. Members are referred to Articles Nos. 34 and 43 on pages 58 of the January, 1954, Journal.

Members who anticipate making a nomination should first make certain that the member they wish to nominate is willing to serve if elected. The nomination should be accompanied by brief biographical notes of the candidate and a note that the candidate is willing for this information to be printed on the battot paper, and that he is willing to serve if elected.

AN INVESTIGATION INTO INDUSTRIAL DESIGN AND DRAWING PRACTICES IN NEW SOUTH WALES, AUSTRALIA

by NO. 1 WORKING GROUP, SYDNEY SECTION,
THE INSTITUTION OF PRODUCTION ENGINEERS

Foreword

This Paper gives the results of an investigation into the design and drawing practices of eighteen engineering organisations in New South Wales. The object of the investigation was to explore the possible economies to be obtained by the adoption of common basic engineering standards in industry. The work incorporates the techniques of a similar project carried out by the Commonwealth Scientific and Industrial Research Organisation, and consists of examining the dimensions and tolerances placed on the detail drawings of a gear pump by the eighteen co-operating industrial firms. The Paper includes a study of each firm's analysis of the given functioning requirements, of the limits and tolerances chosen, and of the drawing practices adopted in the various design offices. A notable point has been the use by the Group of the draft revision to B.S.164 Part I, Limits and Fits for Engineering, and the draft revision to B.S.308, Engineering Drawing Office Practice. The Group used these draft specifications partly to illustrate the use of a comprehensive scheme of preferred sizes, limits and fits and drawing practice, and partly to test their suitability as national standards. Conclusions are submitted dealing with the impact of common basic engineering standards on the economy of Australian engineering, with the suitability of the draft revision to B.S.164 as a national standard and with the use of logical methods of analysing engineering designs as a means to production economy in the individual firm.

THE Sydney Division of the Institution of Engineers, Australia, assisted by the Sydney Section of the Institution of Production Engineers and other co-operating organisations, held an Engineering Production Convention in Sydney in May, 1951, to investigate the structure and use of basic engineering standards. One of the contributions (C. A. Gladman, 1951) which the Commonwealth Scientific and Industrial Research Organisation made to this Convention was an analysis of industrial design and drawing practice, in which the principles and practices used by several engineering organisations in the preparation of drawings for production were investigated. The results of this analysis are included in the Proceedings of the Engineering Production Convention.*

This analysis was noteworthy for a number of features, but particularly for what was termed the design problem technique, which was used to reveal reliable information on design and drawing practices in the co-operating firms. The design problem technique as developed in the analysis involves circulating the drawings of a selected engineering product to a number of engineering firms, these drawings showing the assembly and the details, drawn full-size but not dimensioned, and accompanied by a specification describing the functioning of the product and giving the more important assembly, functioning and interchangeability requirements. Each firm is asked to analyse the design from the information given, select dimensions and tolerances using whatever standards are in use in the firm, and then to prepare the drawings as they would do if the assembly were to be made in their own workshops. Subsequent analysis of each firm's drawings produces a reliable cross-section of the design and drawing practices of the firms concerned. In the C.S.I.R.O. analysis, despite the relatively small number of

* Reprints of the analysis may be obtained on application to the Chief Metrology Division, National Standards Laboratory, Sydney.

participating firms, there were strong grounds for the belief that considerable economies might well be effected if the Australian engineering industry used a common series of preferred sizes, limits and fits and drawing practice, and if there were more knowledge amongst designers and draughtsmen of modern methods of design analysis and of the use of the laws of probability.

Preliminary results of the C.S.I.R.O. analysis were discussed in a Paper presented to the Sydney Section of the Institution of Production Engineers in August, 1951. These results so impressed the Sydney Section Committee of the Institution that they forthwith established a Working Group under the Chairmanship of C. S. Curtis, M.I.Prod.E., to continue the investigation on a broader scale, and thus set an authoritative mark on the findings.

The composition of the Working Group was as follows :

C. S. Curtis, Chairman; R. Barter; H. A. Colton; N. A. Esserman; C. A. Gladman; C. Harris; E. Hewison; J. Rector; H. H. Reid; J. B. Finlay, Secretary.

The Group decided to adopt the design problem technique developed by C.S.I.R.O. to conduct the investigation and the analysis, and furthermore decided to limit the investigation to New South Wales. The Group felt that similar investigations in other States would best be carried out by the appropriate State Section of the Institution of Production Engineers, if the present investigation indicated that to be the most appropriate development. This Paper contains the report of the Working Group on the analysis carried out on its first project, which was commenced in September, 1951 and completed in August, 1952.

Conclusions

Although the number of firms who actually participated in the project was smaller than anticipated, sufficient evidence has been accumulated for the Working Group to form the following conclusions :

1. Considerable economies would be effected in the engineering industry in New South Wales if a common series of preferred sizes, limits and fits and drawing practice were adopted.

In support of this conclusion it is sufficient to point to the information given in Table 2*, where so many different sets of limits have been chosen by the participating firms for the dimensions analysed. It is considered that if each firm had used a common series of basic engineering standards these numbers would have been considerably reduced.

2. The Working Group submit the following conclusions in regard to the new draft revision to B.S.164 incorporating the International Standards Organisation system of limits and fits :

(a) The new draft Standard appears, in general, sufficiently comprehensive for engineering purposes and would probably satisfy most needs as a national Specification.

* All Tables and Figures referred to will be found on pages 216/228.

(b) Some guidance is, however, required as to how best to use this Specification in industry, as with all comprehensive systems of limits and fits. The maximum benefits from its adoption are not likely to be realised until special guidance has been provided.

(c) The Group also consider that improvements could be made by avoiding the necessity for calculating the limits to the half ten-thousandth of an inch when the tolerances themselves are relatively large. The present draft has this weakness. (See fits .5h7U7 and .5h7G7 in Fig. 1.)

(d) During its study, the Group learnt to appreciate the attractiveness of a rational decimal series of preferred numbers as compared with a fractional series.

(e) It would appear that there is little detailed information in the Specification to guide engineers in the selection of holes and shafts when the occasional use of the shaft basis is desired.

The gear pump itself is an example where the shaft basis is necessary for several of the fits.

3. Larger tolerances should, in general, result from the use of modern methods of analysing the functioning requirements of designs, particularly if allowance is made for probability. The Group also considered that more careful thought and attention to production and inspection requirements which such analyses demand will ultimately mean a better shaping of designs to suit production.

Recommendations

The Working Group makes the following recommendations to the Committee of the Sydney Section, Institution of Production Engineers :

1. That the Institution advise the Standards Association of Australia that, as a result of its preliminary and partial survey of sections of Australian industry, it considers the very early completion and issue of B.S.164 " Limits and Fits for Engineering ", and of B.S.308, " Engineering Drawing Office Practice ", a matter of great importance, and that the Standards Association of Australia be requested to urge the British Standards Institution to this effect.

2. That this survey having shown the lack of knowledge of modern systems of limits and fits, drawing office practice and dimensional analysis of engineering designs, the Institution of Production Engineers should take steps to enable management, design staff and production engineers to study these modern principles and practices.

The Design Problem

The design problem chosen by the Working Group was a gear pump for an internal combustion engine which was being manufactured by a particular firm in New South Wales, and for which the design details and specifications were accurately known. The problem, as presented to the engineering firms, was as follows :—

" (1) The attached prints show the assembly and detail drawings for an oil pump of the gear type for a 4-cylinder internal combustion engine. The oil

pump is to maintain a pressure of 18-20 lbs. per square inch when the driving shaft is operating at a speed of 880 rev. per minute.

(2) The pump is operated by means of a helical drive from the cam shaft through the drive gear, Item No. 3, the power being transmitted through the shaft, Item 6, to the driving gear, Item 1, by a Woodruff key, Item 15. The shaft, Item 6, is to be a close running fit in its bearings in the body, Item 5. The driving gear is a press fit on the shaft, Item 6, and is retained there by the circlip, Item 16. When this shaft and gear are assembled in the body, the helical gear, Item 3, is next mounted, positioned, and the shaft drilled from the previously drilled holes in the gear. The pin, Item 4, is then driven in and the ends riveted over. The idler gear, Item 2, which meshes with the driving gear, runs on a journal formed by the pin, Item 7, which is a drive fit in the body. The cover plate, Item 12, is secured to the body by six cheese-headed screws, Item 13, which are each provided with lock washers, Item 14. Interposed between the cover plate and the body is a manilla paper gasket, Item 8. A filter screen, Item 11, retained by a clamp wire, Item 10, completes the assembly. The pump body is located in position in the engine by the long cylindrical portion and is secured by two 5/16″ diameter screws, Item 17.

The method of assembling the driving gear to the shaft is for the gear to be pressed on to the shaft until it is possible to insert the circlip. The gear is then pressed back until the circlip is against the recess face.

(3) With the exception of the filter screen, Item 11, the clamp wire, Item 10, and the lock washer, Item 14, dimension and tolerance all the detail parts shown on the attached prints as you would do if the parts concerned were to be made in your own factory. The parts have been drawn full size, and the drawings should be scaled, as appropriate, to determine nominal sizes for dimensions. The *actual* sizes, limits and tolerances which you show on the drawings should, however, be chosen to suit your own practice, and to conform with any standards for limits and fits, screw threads, surface finish, drawing practice, etc., which you have adopted. Some factories use data sheets to explain the meaning of forms of dimensioning and other practices used on their drawings. If you use such data sheets, it would be appreciated if you would enclose a copy when you return the completed drawings.

(4) In regard to the drawing of Item 5, you are not asked to supply dimensions and tolerances for the outlet ports and passages in the pump body.

(5) In preparing the drawings and determining the limits and tolerances for the various details of this pump it would be appreciated if, within the limits imposed by your own standards, you would conform as closely as possible to the following functioning, assembly and interchangeability requirements. In this way all participating firms will commence the analysis on a common basis, and a more accurate comparison of the practices of the firms will ultimately be possible.

Functioning, Assembly and Interchangeability Requirements:

(A) All parts are to be interchangeable as far as practicable, with the exception contained in paragraph (C) below.

(B) Large quantity production is to be assumed.

(C) The end play of the shaft, Item 6, in the assembled pump is not to be less than .002″ or greater than .005″. (See also method of assembly given in paragraph (2).)

(D) Dimensions and tolerances for the width of the gears, the depth of the pocket in the body and the thickness of the manilla gasket should be chosen so that, with the pump completely assembled, the mean clearance between the width of the gears and the corresponding space in the assembled body should be about .012″. The nominal thickness of the gasket should be about .010″.

(E) The mean clearance of the shaft, Item 6, in its bearings in the body should be about .002″.

(F) The fit between the shaft, Item 6, and the bore of the driving gear, Item 1, should be transition with the mean fit an interference of .0002″.

(G) The mean clearance between the bore of the idler gear, Item 2, and the pin, Item 7, should be about .001″.

(H) The mean interference between the pin, Item 7, and the body should be about .001″.

(K) The mean clearance between the outside diameters of the gears and the diameters of the corresponding recesses in the body should be about .006″.

(L) The backlash for the gears, Items 1 and 2, should not exceed .01″. The gears are each to have ten (10) teeth of 10 diametrical pitch and 20° pressure angle with basic pitch circle diameter equal to 1.0″.

(*Note* : This is not in accordance with normal pump practice which is to cut nine (9) teeth on a ten (10) tooth blank, but has been adopted for simplifying the analysis.)

(M) The Helical Drive Gear, Item 3, is as follows :

No. of teeth	=	10
Helix Angle	=	31° L.H.
Pressure Angle	=	14° – 30′
P . C . D .	=	.833″
D . P .	=	14
Mating Gear	=	11 teeth–1.562″ P.C.D., mating on 1.189″ centres including allowance made for backlash.

(N) The mean clearance between the locating diameter on the body and the corresponding hole in the engine casting should be about .001″."

Drawings of the detail parts were sent with the problem to assist the firms in indicating the dimensions and tolerances for the components. These

drawings merely showed, without dimensions, the outline of each part drawn full size, the material for each part being given on the assembly drawing.

The Industries Co-operating in the Analysis

Firms from the following divisions of industry participated in the investigation :—

Aircraft; Automotive; Gearing Specialists; General Engineers; Defence Establishments; Internal Combustion Engine Manufacturers; Machine Tool Makers; Pump Manufacturers; Transport.

Thirty-six firms were supplied with the problem, and eighteen submitted the analysis.

Analysis

The analysis has been carried out in relation to selected dimensions and elements on nine details of the pump. The dimensions and elements considered were those shown as A, B, C . . . P and encircled in Figures 3 to 10, and the actual sizes and tolerances chosen for these dimensions, etc., by each of the firms are given in the appropriate columns of Table 1. Where the information given in this Table is unqualified, the way in which it is shown in the Table is as it appeared on the firm's drawings. The tolerances for some dimensions could only be found from general notes appearing on the drawings or contained in data sheets supplied by the firm; where this was the case the relevant dimensions have been appropriately marked in Table 1. The sizes and tolerances for a few dimensions were not given directly and had to be obtained by addition or subtraction of other sizes; the relevant dimensions here have also been marked appropriately in Table 1.

For purposes of illustrating the design problem and its solution, the Working Group have prepared firstly, Figure 1, showing the fits chosen for the important parts on the pump; secondly, Figure 2, showing the assembly drawing of the pump; and thirdly, Figures 3 to 10, showing the drawings of the details on which the analysis has been performed. No drawing has been prepared for the screws, Item 17, since only the description of the screw thread was under consideration.

In preparing Figure 1, the Working Group have followed the recommendations contained in the new draft revision to B.S.164 viz. 3rd Proof. C.N.(MEE) 8129 which has been drawn up on the basis of the I.S.O. System for Limits and Fits. The Working Group made this decision after much careful thought and mainly for the following reasons :

(a) because the old B.S.164 was inadequate for the purpose of this design, and

(b) because the exercise of working from the new draft Standard Specification would illustrate how it could be applied in practice, and incidentally be a good test of its scope as an engineering standard.

In using the draft revision to B.S.164 the Working Group had also to choose between the two recommended series of preferred sizes contained therein, the one being a decimal series and the other a fractional or binary series. It was decided finally to adopt the decimal series as being the simpler for use in illustrating the analysis and in preparing the Group's drawings. It was appreciated, however, that the criticism of this action could be that stocks of standard drills, reamers, gauges and the like would not be available for some of the chosen sizes at the present time. Hence the Group's approach to the problem could be regarded as unrealistic. This latter criticism, of course, could be extended at the present time to the entire revision to B.S.164, but if the new draft is subsequently found to be acceptable to the engineering industry as a whole, provision will doubtless be made in due course for the preparation of appropriate specifications for the associated standard drills, reamers, gauges, etc. The main purpose for the Working Group using the new draft as explained hitherto is illustrative, and particularly is to show what can be achieved with a comprehensive and logical scheme of limits and fits.

The fits indicated in Figure 1 for each important pair of mating parts can be identified as follows :

(c) the size given for any pair is the basic size in inches;

(d) the letters following the basic size indicate the relationship of the holes and shafts to the basic size, capital letters referring to holes and small letters to shafts; and

(e) the figures following each letter refer to the grade of hole or shaft as appropriate.

For example, in the fit designated 1.2H9d9 in Figure 1, the basic size is 1.2 inches, the hole is an " H " hole with a grade 9 tolerance and the shaft is a " d " shaft with a grade 9 tolerance. Tables are provided in the draft B.S.164 giving the appropriate limits of tolerance for each hole or shaft in relation to the basic size.

The actual limits and tolerances corresponding to the fits shown in Figure 1 have been included in the appropriate detail drawings shown in Figures 3 to 10. These latter drawings have been prepared on the basis of the draft revision to Sections 12, 13 and 14, Dimensioning and Tolerancing, of B.S.308, viz. C.N.(MEE) 5562. The reasons for choosing to use this Specification are similar to those explained in connection with the use of the draft revision to B.S.164. In the interests of clarity some of the less important dimensions have been omitted from Figures 3 to 10.

In the following the analysis is explained in detail in relation to the eighteen contributing firms.

1. *Analysis with respect to Functioning Requirement F.R.5(D)*

Results of this analysis are given in Table 2. At the foot of this Table are given the sizes and tolerances chosen by the Working Group for the features involved, the necessary calculations being shown in Section 1 of Appendix 1. General observations in regard to this analysis are as follows :

(a) Tolerances quoted for the depth of the pocket, D_5, which is not easy to control precisely in practice, were quite small in some cases,

particularly for Firm 28 (.0005″) and Firms 3 and 16 (.001″).

(b) Only a few firms, viz. Firms 1, 6, 9, 16, 23 and 25, quoted tolerances for the thickness of the gasket.

(c) Most firms obtained values for the mean clearance near that specified. There were only two exceptions, viz. Firms 1 and 7.

2. *Analysis with Respect to F.R. 5E, 5F, 5G and 5H*

Results of these analyses are shown in Tables 3 to 6 respectively. The sizes and tolerances chosen by the Working Group are included at the foot of each Table, complete particulars being given in Sections 2 to 5 of Appendix 1. General observations are as follows:

(a) Most firms adhered closely to the mean values of the given functioning requirements, exceptions being:

(i) Firm 23 had an interference instead of a clearance for F.R. 5E. (See Table 3.)

(ii) Firms 10 and 35 had mean clearances differing appreciably from that quoted for F.R. 5E. (See Table 3.)

(iii) Firms 2, 4, 7 and 28 had a clearance instead of an interference for F.R. 5F. (See Table 4.)

(iv) Firm 8 had a mean clearance of .002 inch instead of .001 inch for F. R. 5G, whilst Firm 19 had an interference instead of a clearance. (See Table 5.)

(v) Firms 4 and 28 had a clearance instead of an interference for F.R. 5H. (See Table 6.)

(b) The average tolerances on the various fits given by the eighteen firms are as follows:

F.R. 5E Table 3 ... ± .00066
F.R. 5F Table 4 ... ± .00053
F.R. 5G Table 5 ... ± .00056
F.R. 5H Table 6 ... ± .00053

(c) The variations in the tolerances quoted for the various fits by the eighteen firms are as follows:

F.R. 5E Table 3 ... ± .00035 to ± .001
F.R. 5F Table 4 ... ± .0002 to ± .0008
F.R. 5G Table 5 ... ± .00035 to ± .001
F.R. 5H Table 6 ... ± .0004 to ± .00085

3. *Analysis with Respect to F.R. 5K*

Results of this analysis are given in Tables 7 and 8, the former Table being concerned only with the clearance between the bore for the gears in the body of the pump and the corresponding external diameter of the gears, whilst Table 8 takes into account the assigned concentricity tolerances and their effect upon the running clearance. As in previous cases, the sizes and tolerances chosen by the Working Group have been included in the Tables, the relevant calculations being shown in Section 6 in Appendix 1. General observations are as follows:

(a) Firms 4, 8 and 28 had mean clearances differing appreciably from that quoted for F.R. 5K. (See Table 7.)

(b) The average tolerance on the mean clearance, chosen by the eighteen firms is ± .0022.

(c) The tolerances on the mean clearance vary from ± .00075 to ± .006.

(d) Only four firms, viz. 1, 16, 25 and 26 quoted tolerances for concentricity in this problem, and hence only these four firms have been included in the analysis for running clearance shown in Table 8.

4. *Analysis with Respect to F.R. 5L*

Results of this analysis are given in Tables 9 and 10, Table 9 showing the calculations required to obtain the mean value for the backlash and Table 10 those required to obtain the variations from the mean. The Working Group's analysis is included at the foot of each Table and the relevant calculations are explained in detail in Section 7, parts (a) and (b) of Appendix 1. In addition, Appendix 2 has been prepared to show the calculations required to determine the diametral limits over rollers for the measurement of the thickness of the gear teeth, and also Appendix 3 to illustrate the analysis for the backlash when allowing for probability. General observations are as follows:

(a) The thickness of the gear teeth was toleranced in three different ways, thus:

(i) Toleranced diametral measurement over specified rollers.
Three firms, viz. Nos. 7, 11 and 25 gave the information in this way. Three other firms, Nos. 2, 10 and 16, gave one dimension over rollers but without tolerances.

(ii) Toleranced chordal width.
Four firms, Nos. 1, 8, 21 and 26, gave the information in this way.

(iii) Toleranced pitch circle diameters.
Three firms, Nos. 3, 6 and 9, gave the information in this way. Five other firms, Nos. 4, 19, 23, 28 and 35, merely quoted the basic pitch circle diameter without tolerances.

(b) Four different sizes of rollers were quoted by the six firms given in (a) (i) above.
Two firms, Nos. 11 and 16, quoted .168 dia. rollers.
Two firms, Nos. 7 and 25, quoted .1728 dia. rollers.
Firm No. 10 quoted .175 dia. rollers
Firm No. 2 quoted .192 dia. rollers.

(c) Only four firms, Nos. 1, 7, 25 and 26, supplied sufficient information *re* tolerances, etc., to enable these to be analysed and checked for conformity with F.R. 5L. Although in no case was there the best agreement with the backlash requirement, nevertheless the final figures for B in Table 10 are generally satisfactory. This is particularly true if it is remembered that the values of E are maximum values and represent the worst possible conditions happening in practice.

5. *Analysis with Respect to F.R. 5N*

No analysis is possible here, as firms did not quote the limits for the hole in the engine body.

6. *Preferred Sizes and Tolerances*

In this analysis the object was to find out how many different limits of size were chosen for certain dimensions on the detail parts of the pump by the various firms. In theory, and provided that two firms are given identical functioning requirements and work on the same system of preferred sizes and limits and fits, they should arrive at identical limits of size for each mating part. This ideal state is unlikely to be realised in practice; nevertheless, less variation between engineering firms might be expected if they all used a common system of basic engineering standards.

The results of this analysis are given in Table 11 and the information in this table is interpreted as follows. Dimension A appearing in Figure 3 is marked 13/18 in Table 11. This means that the eighteen firms between them quoted thirteen different sets of limits for this dimension. Attention is drawn to the following:

(a) Eighteen firms quoted eighteen different sets of limits for dimension B in Figure 4, viz. the bore of the idler gear.

(b) Eighteen firms quoted seventeen different sets of limits for dimension B in Figure 3, viz. the bore of the driving gear.

(c) Eighteen firms quoted fifteen different sets of limits for dimension F in Figure 5, viz. the bore in the body for the idler shaft.

(d) Eighteen firms quoted fifteen different sets of limits for dimension L in Figure 5, viz. the recesses in the body for the gears.

(e) Eighteen firms quoted 9 different sizes and types of screw for dimension M in Figure 5, viz. the threaded holes for the screws securing the cover.

(f) Eighteen firms quoted 12 and 15 different sets of limits respectively for the dimensions A in Figure 6 and 7, viz. the shaft diameters.

(g) Eighteen firms quoted 13 different sets of limits for the dimensions A in Figures 3 and 4, viz. the outside diameters for the gears.

7. *General Drawing Practice*

The results of an analysis, concerned with some of the more important aspects of the drawing practice used by the firms in preparing their entries, is shown in Table 13. The main features are as follows:

(a) Most firms use decimals for important dimensions, and fractions for unimportant sizes.

(b) Ten of the eighteen firms have a general note to cover the untoleranced dimensions.

(c) Twelve firms used both hole and shaft basis, four firms used shaft basis alone, while Firm 26 worked on unilateral hole basis to the extent of a three-stepped shaft (Item 6).

(d) Unilateral tolerances for important fit sizes were used by fourteen firms, one firm used bilateral tolerances only, while another three firms worked to both systems.

(e) Consistent application of B.S.164 Limits and Fits System was observed in the design of only three firms. No firm used the Newall System.

(f) Important dimensions were expressed as limits of size by three firms, as design size and tolerances by ten firms, while one firm adopted the basic size and limits of tolerance notation. A combination of two of the three methods was used by the remaining four firms.

(g) Surface finish symbols were omitted by five firms, while Firm 1 used the U.S. "check" symbol and a micro-inch roughness value. Two firms used the S.A.A. symbols, two used the inverted triangle and seven others adopted the "f", "G", etc. notation, while Firm 7 used a combination of triangle and "f" symbols.

(h) Six of the eighteen firms quoted one or more of the tolerances for concentricity, straightness, squareness, etc., the maximum number of firms, quoting a specified dimension, being four. (See Table 12.)

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The Tables and Figures referred to above will be found on the pages following:

Appendices appear on pages 228/232.

Φ FROM GENERAL TOLERANCE NOTES

TABLE 1

* INDICATES DERIVED DIMENSIONS

DIMENSION	FIRM 1 ITEM									FIRM 2 ITEM									FIRM 3 ITEM								
	1	2	5	6	7	8	12	15	17	1	2	5	6	7	8	12	15	17	1	2	5	6	7	8	12	15	17
Ⓐ	1·200 −1/2	1·200 −1/2	1·000 +5 −5	·4985 −1/2	·5015 −1/2	·010 +1 −1	·525 +5 −5	·625 −5	5/16 WHIT	1·200 +·000 −·001	1·200 +·000 −·001	1 ± 1/64 Φ	·498 ±·0005	·5005 +·0002 −·0000	·010 ±·005 Φ	9/16 ± 1/64 Φ	·500 +·000 −·010	5/16 BSW	1·2 +·000 −·006	1·2 +·000 −·006	1 ±·005	1/2 −·0012 −·0020	1/2 +·0016 +·0012	·01	9/16 ±·003	1/4 R +·0000 −·0025	5/16 B.S.W
Ⓑ	·4978 +1/2	·502 +1/2	·500 +5 −5	·625 +10			·1719 +5	·250 −5		·4992 +·0005 −·0000	·5012 +·0005 −·0000	1/2 ± 1/64 Φ	·500 ± ·005 Φ			N°19 ·166 DRILL	·203 ±·015 Φ		·4982 ±·0004	·5024 ±·0004	1/2 ±·003	N° 2 B.S. WOODRUFF			11/64 DRILL	.203 +·000 −·005	
Ⓒ	1·245 −1	1·245 −1	·328 +5	·1981 +5				·0948 −1		1·250 ±·001	1·250 ±·001	3/8 DRILL	·135 +·005 −·000				·125 +·001 −·000		1·249 +·000 −·001	1·249 +·000 −·001	11/32 DRILL	·151 +·005 −·000				·095 +·000 −·001	
Ⓓ	CHORDAL WIDTH		1·250 +3	·0928 +1						·192	·192	1·252 +·002 −·000	·124 +·001 −·000						PITCH DIA LIMITS		1 1/4 +·001 −·000	—					
Ⓔ	·1544 −3	·1544 −3	·500 +1/2	—						1·3441	1·3441	·500 ±·0005	±·001						1 −·005 −·008	1 −·005 −·008	1/2 +·0008 −·0000	—					
Ⓕ	0948 +1		·500 +1/2							·126 +·001 −·000		·500 ±·0005							·095 +·001 −·000		1/2 +·0008 −·0000						
Ⓖ	·306 +5 TO Ⓔ		1·000 +1							·320 TO Ⓔ +·005 −·000		—							·057 ON Ⓔ +·005 −·000		* 1 ±·004						
Ⓗ	·0005 AT SR	·0005 AT SR	9·800 −10							—	—	*9·625 +·004 −·002							—	—	9 5/8 ± 1/64 Φ						
Ⓚ	·0005	·0005	·9995 −1/2							—	—	·999 +·000 −·001							—	—	1 +·0008 −·0006						
Ⓛ	·0015	·0015	1·205 +1							—	—	1·204 +·002 −·000							—	—	1·206 ±·003						
Ⓜ			3 BA									3 BA									5/32 B.S.W.						
Ⓝ			—									—									—						
Ⓟ			·001									—									—						

TABLE 1 (CONTINUED)

DIMENSION	FIRM 4 ITEM									FIRM 6 ITEM									FIRM 7 ITEM								
	1	2	5	6	7	8	12	15	17	1	2	5	6	7	8	12	15	17	1	2	5	6	7	8	12	15	17
Ⓐ	1·200 ±·001	1·200 ±·001	1	·4998 +·0000 −·0002	·4993 +·0007 −·0000	—	* ·5	·250R +·000 −·0025	5/16 B.S.F.	1·200 +·000 −·002	1·200 +·000 −·002	1 ±·005 Φ	·500 ±·0000 −·0005	·500 +·0000 −·0005	·016 ±·002	9/16 ±·005 Φ	·500 +·000 −·010	5/16 B.S.F	1·200 ±·001	1·200 ±·001	1·000 ±·005	·4985 +·0000 −·0005	·5008 +·0004 −·0000	·015	17/32	1/2	5/16 WHIT
Ⓑ	·5000 +·0002 −·0000	·5007 +·0007 −·0000	·5	·500 +·000 −·005			5/32 DRILL	·203 +·000 −·005		·4998 +·0000 −·0005	·5005 +·0005 −·0000	1/2 ± ·005 Φ	1/2 ±·005 Φ			N°19 ·166 DRILL	·203 +·000 −·005		·4990 +·0004 −·0000	·5016 +·0004 −·0000	·500 ±·005	1/2			7/32 DRILL	—	
Ⓒ	1·250 +·002 −·000	1·250 +·002 −·000	5/16 DRILL	·355 +·002 −·000 TO Ⓔ				·0948 +·000 −·001		1·250 ±·001	1·258 ±·001	11/32 DRILL	·1355 +·005 −·000				·126 +·000 −·001		1·250 +·000 −·002	1·250 +·000 −·002	11/32 DRILL	·1511 +·0050 −·0000				3/32	
Ⓓ	—	—	1·262 +·002 −·000	—				N°20 WOODRUFF		PITCH DIA LIMITS		1·252 ±·002	·124 +·0015 −·0000						·1728	·1728	1·271 ± 001	·0928 +·0015 −·0000					
Ⓔ	—	—	·502 +·000 −·001	—						1·000 +·000 −·003	1·000 +·000 −·003	·5015 +·0015 −·0000	—						1·2322 +·0000 −·0014	1·2322 +·0000 −·0014	·5000 +·0010 −·0000	—					
Ⓕ	·126 +·005 −·000		·501 +·001 −·000							·131 +·000 −·005		·499 +·0000 −·0005							·0937 +·0000 −·0010		·5000 +·0004 −·0000						
Ⓖ	·307 +·005 −·000 TO Ⓔ		1·000 ± ·002						−·005	·073 +·000 AT EDGE		1·002 ±·002							·062 ±·005 AT EDGE		1·000 +·002 −·000						
Ⓗ	—	—	9·562 +·005 −·000							—	—	9 5/8 ±·005 Φ							—	—	9·625 ±·005						
Ⓚ	—	—	·999 +·000 −·001							—	—	·9995 +·0000 −·0005							—	—	·999 +·000 −·001						
Ⓛ	—	—	·606R +·001 −·000							—	—	1·205 ±·002							·002	·002	1·206 +·002 −·000						
Ⓜ			48A.									3 BA.									10 SAE						
Ⓝ			—									—									—						
Ⓟ			—									—									—						

TABLE I (CONTINUED)

DIMENSION	FIRM 8									FIRM 9									FIRM 10								
	ITEM									ITEM									ITEM								
	1	2	5	6	7	8	12	15	17	1	2	5	6	7	8	12	15	17	1	2	5	6	7	8	12	15	17
(A)	1.1992 +.0000 −.0012	1.1992 +.0000 −.0012	1.000 ±.005	.4988 +.0000 −.0008	.5016 +.0000 −.0004	—	.500 ±.005	.500 +.000 −.005	5/16 B.S.F.	1.200 ±.001	1.200 ±.001	■1.000 ±.0025	.4902 ±.0003	.4890 ±.0003	.0100 ±.0005	■ 9/16 ±.001	.495 ±.005	5/16 WHIT.	1.200 −.002 −.004	1.200 −.002 −.004	1 ±1/64 Φ	1/2 −.0005 −.0010	1/2 −.0005 −.0010	.010	■ 9/16 ±1/64 Φ	1/2 +.000 −.005	5/16 WHIT.
(B)	.4980 +.0004 −.0006	.5028 +.0012 −.0000	.500 ±.005	.500 +.000 −.005			—	.203 +.000 −.005		.4900 ±.0003	.4900 ±.0003	.500 ±.005	.505 ±.005			.190 ±.002	.2005 ±.0025		1/2 −.0005 −.0015	1/2 +.001 −.0000	1/2 ±1/64 Φ	1/2 ±1/64 Φ			3/16 ±1/64 Φ	13/64 +.000 −.005	
(C)	1.250 +.000 −.002	1.250 +.000 −.002	—	.349 +.000 −.005				.0948 +.000 −.001		1.3100 ±.0005	1.3100 ±.0005	5/16 DRILL	.154 ±.003				.0943 ±.0005		1 1/4 ±.002	1 1/4 ±.002	3/8 ±1/64 Φ	—				1/8 ±.001	
(D)	CHORD WIDTH		1.250 +.002 −.000	.0928 +.001 −.000						PITCH DIA. LIMITS:		1.3125 ±.001	.0935 ±.0005						.175	.175	1 1/4 ±.002	1/8 ±1/64 Φ					
(E)	.153 .155	.153 .155	.500 +.0005 −.0000	—						1.000 ±.001	1.000 ±.001	.4920 ±.0005	—						1.236	1.236	1/2 +.001 −.000	—					
(F)	.0948 +.001 −.000		.500 +.0005 −.0000							.0935 ±.0005		.4890 ±.0003							1/8 +.000 −.002		1/2 −.0015 −.0020						
(G)	.057 +.005 −.000		1.0000 ±.0005							.055 ±.003 AT EDGE		1.005 ±.001							1/16 +.005 −.000		1 ±.002						
(H)	—	—	—							—	—	9 5/8 ±1/32 Φ							—	—	9 5/8 ±.005						
(K)	—	—	1.0000 +.0005 −.0006							—	—	1.000 ±.001							—	—	1 ±1/64 Φ						
(L)	—	—	1.200 +.0012 −.0000							—	—	1.206 ±.002							—	—	1.200 +.002 −.000						
(M)			3/16 * B.S.F.									3/16 WHIT.									5/32 WHIT.						
(N)			—									—									—						
(P)			—									—									—						

TABLE I (CONTINUED)

DIMENSION	FIRM 11									FIRM 16									FIRM 19								
	ITEM									ITEM									ITEM								
	1	2	5	6	7	8	12	15	17	1	2	5	6	7	8	12	15	17	1	2	5	6	7	8	12	15	17
(A)	1.200 +0 −.003	1.200 +0 −.003	1	.5000 +0 −.0004	.500 +0 −.0004	—	17/32	1/2	5/16 B.S.W.	1.2005 1.1995	1.2005 1.1995	1	.5000 .4998	.5000 .4998	.011 .009	17/32 J I 6.	.500 +.000 −.010	* 5/16 WHIT	1.200 1.198	1.200 1.198	.995 1.005	.4986 .4982	.4998 .4990	.010	.495 .505	1/2	5/16 B.S.W.
(B)	.4992 +.0008 −0	.5004 +.0008 −0	1/2	№ 2 WOODRUFF			7/32 DRILL	.203 +0 −.005		.4994 .4998	.5005 .5015	1/2	.500			9/32 DRILL	.203 +.000 −.005		.4978 .4986	.4978 .4986	.495 .505	1/2 ±1/64 Φ			7/32 ±1/64 Φ	—	
(C)	1.250 +0 −.002	1.256 +0 −.002	11/32 DRILL	.1541 +.005 −0				.0948 +0 −.001		1.250 1.249	1.250 1.249	11/32 J I 6.	.151 +.005 −.000				.0938 +.001 −.000		1.250 1.248	1.250 1.248	11/32 ±1/64 Φ	.1355 .1405				1/8	
(D)	.168	.168	1.256 +.002 −0	—						.168	.168	1.251 1.252	.0928 +.0015 −.000						—	—	1.248 1.252	.1240 .1255					
(E)	1.211 +0 −.002	1.211 +0 −.002	.5016 +.0604 −0	—						1.211	1.211	.5015 .5020	—						—	—	.5008 .5000	—					
(F)	.0948 +.002 −0		.4984 +.0008 −0							.0948 +.002 −.000		.4985 .4995							.126 .130		.4988 .4980						
(G)	.5050 +.005 −0 ON ℄		1.000 +0 −.003							.0529 +.005 −.000 AT EDGE		1.000 1.002							.565 .570		2.002 1.998						
(H)	—	—	9 5/8							—	—	9 5/8							—	—	9 5/8 ±1/64 Φ						
(K)	—	—	1.000 +0 −.0006							.001	.001	1.000							—	—	.998 1.000						
(L)	—	—	1.203 +.003 −0							—	—	1.2055 1.2065							—	—	1.206 1.203						
(M)			* 3/16 B.S.W.									1/4 WHIT.									2BA						
(N)			—									.0008									—						
(P)			—									.0015									—						

TABLE 1 (CONTINUED)

DIMENSION	FIRM 21 ITEM									FIRM 23 ITEM									FIRM 25 ITEM								
	1	2	5	6	7	8	12	15	17	1	2	5	6	7	8	12	15	17	1	2	5	6	7	8	12	15	17
(A)	1·200 −·0048 −·0072	1·200 −·0048 −·0072	* 1 +·0005 −·0005	1/2 −·003 −·0034	1/2 −·0030 −·0034	—	9/16 ±·002	1/2 +·000 −·005	5/16 MED B.S.W	1·200 +·000 −·002	1·200 +·00 −·002	* 1 ±·0025 Ⓟ	1/2 a) −·0000 −·0002 b) −·0015 −·0025	1/2 a) −·001 −·002 b) −·0000 −·0002	·010 ±·002	*19/32 ±·005 Ⓟ	·490 ·500	5/16 B.S.W	1·200 +·00 −·001	1·200 +·00 −·001	*1·000 ±·0025 Ⓟ	·500 +·00 −·0004	·500 +·00 −·0004	·01 ±·002	·562 ±·005	·500 +·0 −·01	5/16 B.S.F
(B)	1/2 −·0030 −·0038	1/2 −·0018 −·0026	1/2 ±·001	N°2 WOODRUFF			13/64	·203 +·000 −·005		1/2 +·000 −·0002	·5005 ·4995	1/2 ±·005 Ⓟ	·490 ·500			11/64 ±·005 Ⓟ	·198 ·203		·4993 +·0006	·5005 +·0006	·500 ±·005 Ⓟ	·500 +·0 ±·005 Ⓟ			·1770 +·003 −·00	·203 −·005	
(C)	1 1/4 −·000 −·001	1 1/4 +·000 −·001	"O" DRILL	·151 +·005 −·000				·0948 +·000 −·001		1 3/16 +·000 −·003	1 3/16 +·000 −·003	3/8 ±·005 Ⓟ	·1511 ·1561				·0938 ·0948		·1250 +·00 −·001	·1250 +·00 −·001	11/32	·1514 +·005 −·00				·0948 +·0 −·001	
(D)	CHORD WIDTH		1 1/4 +·004 −·000	·0928 +·001 −·000				N°20 B.S. KEY		—	—	1 3/16 −·000 +·003	·0928 ·0943						·1728	·1728	·1250 +·002 −·00	·0928 +·0005 −·00					
(E)	·1524 ·1544	·1524 ·1544	1/2 −·0008 −·0016	—						—	—	·5005 ·4995	—						·1226 +·00 −·001	·1226 +·00 −·001	·5010 +·001	·003					
(F)	·0948 +·001 −·000		1/2 −·0035 −·00425							·0948 ·0948		1/2 −·0002 −·0008							·0948 +·002		·4985 ·4991						
(G)	·554 +·005 −·000 ON ℄		1·000 ±·0005							·0529 ·0579 AT EDGE		1 +·0065 +·0115							·5480 +·003 −·00 ON ℄		1·000 +·002 −·00						
(H)	—	—	9 5/8 ±·010							—	—	9 9/16 ±·005 Ⓟ							—	—	9·62 ±·015 Ⓟ						
(K)	—	—	1 +·0000 −·0006							—	—	1 −·001 −·002							·002	·002	1·00 +·0 −·001						
(L)	—	—	1·200 ±·0006							—	—	1·200 +·008 +·002							·001	·001	1·205 +·001 −·00						
(M)			3/16 MED FIT B.S.W.									5/32 B.S.W.									3.8 A						
(N)			—									—		NOTE. SHAFTS 6 & 7 STEPPED FOR a) FIT IN GEAR b) FIT IN BODY							ZERO						
(P)			—									—									·002						

TABLE 1 (CONTINUED)

DIMENSION	FIRM 26 ITEM									FIRM 28 ITEM									FIRM 35 ITEM								
	1	2	5	6	7	8	12	15	17	1	2	5	6	7	8	12	15	17	1	2	5	6	7	8	12	15	17
(A)	1·199 1·195	1·199 1·195	1·000 ±·0005	a) ·5005 ·5004 b) ·4988 ·4980	a) ·5016 ·4992 b) ·5016 ·5012	—	* ·5325 ±·0025	·500 −·005	5/16 CLASS 2 IB N.C.	1·198 +·001	1·198 +·001	* 1	·4995 +·0005	·4995 +·005	—	9/16	·490 +·005	5/16 WHIT	1·200 1·202	1·200 1·202	* 1	·4847 ·4850	·4847 ·4850	·010	9/16	·490 ·500	5/16 NC/2
(B)	·5008 ·5000	·5008 ·5000	·500 ±·0005	1/2			·184 ±·004	·203 −·005		·500 +·0005	·501 +·0005	1/2	1/2			9/32	·198 +·005		·4844 ·4850	·4862 ·4852	1/2	1/2			3/16 DRILL	·198 ·203	
(C)	1·246 1·242	1·246 1·242	·3446 −·005	·1511 +·005				·0948 −·001		1·249 +·0005	1·249 +·0005	11/32 DRILL	·151 +·005				·093 +·001		1·250 1·252	1·250 1·252	11/32	·1511 ·1561				·0938 ·0948	
(D)	CHORD WIDTH		1·249 1·243	·0948						—	—	1·250 +·0005	·093 +·001						—	—	1·254 1·252	·0928 ·0943					
(E)	·1537 ·1554	·1537 ·1554	·500 +·0008	—						—	—	·501 +·0005	—						—	—	·4865 ·4855	—					
(F)	·0948 +·001		·500 +·0008							·095 +·002		·500 +·0005							·0948 ·0968		·4835 ·4845						
(G)	·057 +·005 AT EDGE		1·000 +·002							·053 +·005		·999 +·002							·0529 ·0579		1·003 1·005						
(H)	—	—	9·5625 ±·005							ZERO	ZERO	—							—	—	—						
(K)	·0005	·0005	·9999 ·9993							—	—	·999 +·001							—	—	1·000 ·9995						
(L)	·0005	·0005	1·202 +·002							—	—	1·200 +·001							—	—	1·206 1·208						
(M)			N° 8 x 32 N.C.									1/4 WHIT.									N° 8 N.C./2						
(N)			·0005		NOTE. SHAFTS 6 & 7 STEPPED FOR a) FIT IN GEAR b) FIT IN BODY							—									—							
(P)			ZERO									—									—						

TABLE 1 (CONTINUED)

DIMENSION	WORKING GROUP STANDARD — ITEM 1	2	5	6	7	8	12	15	17
(A)	1·1969 1·1945	1·1969 1·1945	1·0 (P.T.)	·5000 ·4993	·5000 ·4993	·011 ·009	·55 (P.T.)	·500 ·495	3/8–16 UNC-2A
(B)	·49975 ·49905	·50095 ·50025	·5 (P.T.)	·500 ·495			·200 +·005	·203 ·198	
(C)	1·2500 1·2461	1·2500 1·2461	·400 +·007	·1561 ·1511				·0948 ·0938	
(D)	·168	·168	1·2524 1·2476	·0928 ·0918					
(E)	1·2191 1·2128	1·2191 1·2128	·5020 ·5013	·001					
(F)	·0958 ·0948		·49895 ·49825						
(G)	·557 +·007 ON £		1·0015 (P.T.)						
(H)	·003	·003	9·625 ±·018Φ						
(K)	·001	·001	1·0000 ·9992						
(L)	·001	·001	1·2024 1·2000						
(M)			2BA MED.						
(N)			·0005						
(P)			·0015						

TABLE 2

FUNCTIONING REQUIREMENT $_5$D

$$Cl = D_5 + A_8 - C_1 \pm \tfrac{1}{2}(\delta d + \delta a + \delta c)$$

Firm No.	DIMENSION D_5 (Item 5)	C_1 (Item 1)	A_8 (Item 8)	Cl
1	1·251 5 ± ·001 5	1·244 5 ± ·000 5	·010 ±·001	·016 75 ±·003 25
2	1·253 ± ·001	1·250 ± ·001	·010	·013
3	1·250 5 ± ·000 5	1·248 5 ± ·000 5	·010	·012
4	1·263 ± ·001	1·251 ± ·001	·010	·012
6	1·252 ± ·002	1·250 ± ·001	·010 ±·002	·012 ±·005
7	1·271 ± ·001	1·249 ± ·001	·015	·037
8	1·251 ± ·001	1·249 ± ·001	·010	·012
9	1·312 5 ± ·001	1·310 0 ± ·000 5	·010 ±·000 5	·012 5 ±·002
10	1·250 ± ·002	1·250 ± ·002	·010	·010
11	1·251 ± ·001	1·249 ± ·001	·010	·012
16	1·251 5 ± ·000 5	1·249 5 ± ·000 5	·010 ±·001	·012 ±·002
19	1·250 ± ·002	1·249 ± ·001	·010	·011
21	1·252 ± ·002	1·249 5 ± ·000 5	·010	·012 5
23	1·189 ± ·001 5	1·186 ± ·001 5	·010 ±·002	·013 ±·005
25	1·251 ± ·001	1·249 5 ± ·000 5	·010 ±·002	·011 5 ±·003 5
26	1·246 ± ·003	1·244 ± ·002	·010	·012
28	1·250 25 ± ·000 25	1·249 25 ± ·000 25	·010	·011
35	1·253 ± ·001	1·251 ± ·001	·010	·012
Working Group	1·250 ± ·002 4	1·248 05 ± ·001 95	·010 ±·001	·011 95 ±·005 35

TABLE 3

FUNCTIONING REQUIREMENT $_5E$

$$C = E_5 - A_6 \pm \tfrac{1}{2}(\delta E + \delta A)$$

Firm No.	Dimension		Clearance C	Firm No.	Dimension		Clearance C
	E_5 (Item 5)	A_6 (Item 6)			E_5 (Item 5)	A_6 (Item 6)	
1	·500 25 ±·000 25	·498 25 ±·000 25	·002 0 ±·000 5	16	·501 75 ±·000 25	·499 9 ±·000 1	·001 85 ±·000 35
2	·500 0 ±·000 5	·498 0 ±·000 5	·002 0 ±·001 0	19	·500 4 ±·000 4	·498 4 ±·000 2	·002 0 ±·000 6
3	·500 4 ±·000 4	·498 4 ±·000 4	·002 0 ±·000 8	21	·498 8 ±·000 4	·496 8 ±·000 2	·002 0 ±·000 6
4	·501 5 ±·000 5	·499 7 ±·000 1	·001 8 ±·000 6	23	·500 0 ±·000 5	·500 1 ±·000 1	—·000 1 ±·000 6
6	·502 25 ±·000 75	·499 75 ±·000 25	·002 5 ±·001 0	25	·501 5 ±·000 5	·499 8 ±·000 2	·001 7 ±·000 7
7	·500 5 ±·000 5	·498 25 ±·000 25	·002 25 ±·000 75	26	·500 4 ±·000 4	·498 4 ±·000 4	·002 0 ±·000 8
8	·500 4 ±·000 4	·498 4 ±·000 4	·002 0 ±·000 8	28	·501 25 ±·000 25	·499 75 ±·000 25	·001 5 ±·000 5
9	·492 25 ±·000 25	·490 2 ±·000 3	·002 05 ±·000 55	35	·486 0 ±·000 5	·484 85 ±·000 15	·001 15 ±·000 65
10	·500 5 ±·000 5	·499 25 ±·000 25	·001 25 ±·000 75	Work'g Group	·501 65 ±·000 35	·499 65 ±·000 35	·002 ±·000 7
11	·501 8 ±·000 2	·499 8 ±·000 2	·002 0 ±·000 4				

TABLE 9

FUNCTIONING REQUIREMENT $_5L$

$$B = (S - T) + \text{Tan } \varphi[(D_1 - D_2) + (D_5 - D_4)] + 2d \text{ Tan } \varphi \text{ approx.}$$

Firm No.	Size of Rollers	Dia. over Rollers Z	Basic Dia. over Rollers Z_B	Chord Width W	Basic Chord Width W_B	K	$\frac{1}{K}(Z_B - Z)$ or $W_B - W$	$S - T = \frac{2}{K}(Z_B - Z)$ mean or $2(W_B - W)$ mean	$(D_1 - D_2) + \ldots$	$(\text{Tan } \varphi) \times [(D_1 - D_2) + \ldots]$	d	2d Tan φ	B Mean Value
1	—	—	—	·154 4 ·151 4	·156 4	—	·002 0 ·005 0	·007 0	·003 0	·001 1	∓·000 5	·000 4	·008 5
7	·172 8	1·232 4 1·230 8	1·234 4	—	—	2·01	·001 1 ·001 8	·002 9	·003 05	·001 1	+·001	·000 7	·004 7
25	·172 8	1·226 0 1·225 0	1·234 4	—	—	2·01	·004 2 ·004 7	·008 9	·002 7	·001 0	+·001	·000 7	·010 6
26	—	—	—	·155 4 ·153 7	·156 4	—	·001 0 ·002 7	·003 7	·003 0	·001 1	+·001	·000 7	·005 5
Working Group	·168	1·219 1 1·212 8	1·219 1	—	—	2·10	0 ·003	·003 0	·002 95	·001 1	+·001 5	·001 1	·005 2

TABLE 4

FUNCTIONING REQUIREMENT 5F

$$I = A_6 - B_1 \pm \tfrac{1}{2}(\delta a + \delta b)$$

Firm No.	Dimension		Interference I	Firm No.	Dimension		Interference I
	A_6 (Item 6)	B_1 (Item 1)			A_6 (Item 6)	B_1 (Item 1)	
1	·498 25 ±·000 25	·498 05 ±·000 25	·000 2 ±·000 5	16	·499 9 ±·000 1	·499 6 ±·000 2	·000 3 ±·000 3
2	·498 0 ±·000 5	·499 45 ±·000 25	−·001 45 ±·000 75	19	·498 4 ±·000 2	·498 2 ±·000 4	·000 2 ±·000 6
3	·498 4 ±·000 4	·498 2 ±·000 4	·000 2 ±·000 8	21	·496 8 ±·000 2	·496 6 ±·000 4	·000 2 ±·000 6
4	·499 7 ±·000 1	·500 1 ±·000 1	−·000 4 ±·000 2	23	·500 1 ±·000 1	·499 9 ±·000 1	·000 2 ±·000 2
6	·499 75 ±·000 25	·499 55 ±·000 25	·000 2 ±·000 5	25	·499 8 ±·000 2	·499 6 ±·000 3	·000 2 ±·000 5
7	·498 25 ±·000 25	·499 2 ±·000 2	−·000 95 ±·000 45	26	·500 6 ±·000 2	·500 4 ±·000 4	·000 2 ±·000 6
8	·498 4 ±·000 4	·498 2 ±·000 2	·000 2 ±·000 6	28	·499 75 ±·000 25	·500 25 ±·000 25	−·000 5 ±·000 5
9	·490 2 ±·000 3	·490 0 ±·000 3	·000 2 ±·000 6	35	·484 85 ±·000 15	·484 7 ±·000 3	·000 15 ±·000 45
10	·499 25 ±·000 25	·499 0 ±·000 5	·000 25 ±·000 75	Work'g Group	·499 65 ±·000 35	·499 4 ±·000 35	·000 25 ±·000 7
11	·499 8 ±·000 2	·499 6 ±·000 4	·000 2 ±·000 6				

TABLE 10

FUNCTIONING REQUIREMENT 5L—*Continued*

$$E = \text{Tan } \varphi \; [\pm p_1 \pm p_7 \pm p_t \pm p_t] \pm \frac{\delta S}{2} \pm \frac{\delta T}{2}$$

Firm	p_1+p_7	p_t	$p_1+p_7+\ldots$	(Tan φ) x $(p_1+p_7+\ldots)$	$\frac{\delta S}{2}$ or $\frac{\delta T}{2}$	E Max.	B (See also Table 9)
1	·001	·001 5	·004	·001 5	·001 5	·004 5	·008 5 ± ·004 5
7	·002	·002	·006	·002 2	·000 35	·002 9	·004 7 ± ·002 9
25	·002	·001	·004	·001 5	·000 25	·002 0	·010 6 ± ·002 0
26	·002	·000 5	·003	·001 1	·000 85	·002 8	·005 5 ± ·002 8
Working Group	·003	·001	·005	·001 8	·001 5	·004 8	·005 2 ± ·004 8

TABLE 5 FUNCTIONING REQUIREMENT 5G

$C = B_2 - A_7 \pm \frac{1}{2}(\delta b + \delta a)$

Firm No.	Dimension		Clearance C	Firm No.	Dimension		Clearance C
	B_2 (Item 2)	A_7 (Item 7)			B_2 (Item 2)	A_7 (Item 7)	
1	·502 25 ±·000 25	·501 25 ±·000 25	·001 0 ±·000 5	16	·501 0 ±·000 5	·499 9 ±·000 1	·001 1 ±·000 6
2	·501 45 ±·000 25	·500 6 ±·000 1	·000 85 ±·000 35	19	·498 2* ±·000 4	·499 4 ±·000 4	+·001 2 ±·000 8
3	·502 4 ±·000 4	·501 4 ±·000 2	·001 0 ±·000 6	21	·497 8 ±·000 4	·496 8 ±·000 2	·001 0 ±·000 6
4	·501 05 ±·000 35	·499 65 ±·000 35	·001 4 ±·000 7	23	·500 0 ±·000 5	·498 5 ±·000 5	·001 5 ±·001
6	·500 75 ±·000 25	·499 75 ±·000 25	·001 0 ±·000 5	25	·500 8 ±·000 3	·499 8 ±·000 2	·001 8 ±·000 5
7	·501 8 ±·000 2	·501 0 ±·000 2	·000 8 ±·000 4	26	·500 4 ±·000 4	·499 4 ±·000 2	·001 0 ±·000 6
8	·503 4 ±·000 6	·501 4 ±·000 2	·002 0 ±·000 8	28	·501 25 ±·000 25	·499 75 ±·000 25	·001 5 ±·000 5
9	·490 0 ±·000 3	·489 0 ±·000 3	·001 0 ±·000 6	35	·485 7 ±·000 5	·484 85 ±·000 15	·000 85 ±·000 65
10	·500 5 ±·000 5	·499 25 ±·000 25	·001 25 ±·000 75	Work'g Group	·500 6 ±·000 35	·499 65 ±·000 35	·000 95 ±·000 7
11	·500 8 ±·000 4	·499 8 ±·000 2	·001 0 ±·000 6				

* Probably an error.

TABLE 11 VARIATION IN STATED DIMENSIONS

Dimension	Item 1 Fig. 3	Item 2 Fig. 4	Item 5 Fig. 5	Item 6 Fig. 6	Item 7 Fig. 7	Item 8 Fig. 8	Item 12 Fig. 9	Item 15 Fig. 10	Item 17
A	13/18	13/18	4/13	12/18	15/17	6/12	14/18	4/15	3/18
B	17/18	18/18	5/13	6/10	—	—	14/17	5/16	—
C	11/18	11/18	9/15	10/17	—	—	—	7/16	—
D	4/6	4/6	13/18	8/14	—	—	—	—	—
E	*	*	13/18	—	—	—	—	—	—
F	11/18	—	15/18	—	—	—	—	—	—
G	15/18	—	12/17	—	—	—	—	—	—
H	—	—	9/13	—	—	—	—	—	—
K	—	—	9/17	—	—	—	—	—	—
L	—	—	15/18	—	—	—	—	—	—
M	—	—	9/18	—	—	—	—	—	—

* Gear Tooth Measurement—See Table 9.

TABLE 6 FUNCTIONING REQUIREMENT 5H

$$I = A_7 - F_5 \pm \tfrac{1}{2}(\delta a + \delta f)$$

Firm No.	Dimension		Interference I	Firm No.	Dimension		Interference I
	A_7 (Item 7)	F_5 (Item 5)			A_7 (Item 7)	F_5 (Item 5)	
1	·501 25 ±·000 25	·500 25 ±·000 25	·001 0 ±·000 5	16	·499 9 ±·000 1	·499 0 ±·000 5	·000 9 ±·000 6
2	·500 6 ±·000 1	·500 0 ±·000 5	·000 6 ±·000 6	17	·499 4 ±·000 4	·498 4 ±·000 4	·001 0 ±·000 8
3	·501 4 ±·000 2	·500 4 ±·000 4	·001 0 ±·000 6	21	·496 8 ±·000 2	·496 125 ±·000 375	·000 675 ±·000 575
4	·499 65 ±·000 35	·501 5 ±·000 5	−·001 85 ±·000 85	23	·499 9 ±·000 1	·499 5 ±·000 3	·000 4 ±·000 4
6	·499 75 ±·000 25	·498 75 ±·000 25	·001 0 ±·000 5	25	·499 8 ±·000 2	·499 8 ±·000 3	·001 0 ±·000 5
7	·501 0 ±·000 2	·500 2 ±·000 2	·000 8 ±·000 4	26	·501 4 ±·000 2	·500 4 ±·000 4	·001 0 ±·000 6
8	·501 4 ±·000 2	·500 4 ±·000 4	·001 0 ±·000 6	28	·499 75 ±·000 25	·500 25 ±·000 25	−·000 5 ±·000 5
9	·489 0 ±·000 3	·488 0 ±·000 3	·001 0 ±·000 6	35	·484 85 ±·000 15	·484 0 ±·000 5	·000 85 ±·000 65
10	·499 25 ±·000 25	·498 25 ±·000 25	·000 0 ±·000 5	Work'g Group	·499 65 ±·000 35	·498 6 ±·000 35	·001 05 ±·000 7
11	·499 8 ±·000 2	·498 8 ±·000 4	·001 0 ±·000 6				

TABLE 13 ANALYSIS OF GENERAL DRAWING PRACTICE

Firms Indicated by "X" Commonly Use:	Code Number for Firms in the Analysis																
	1	2	3	4	6	7	8	9	10	11	16	19	21	23	25	26	28	35
Decimals for important dimensions	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fractions for important dimensions ...			X						X				X	X				
Decimals for unimportant dimensions	X			X														
Fractions for unimportant dimensions		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Overall tolerance note	X	X	X		X			X	X			X		X	X	X		
Hole basis	X	X	X	X	X	X	X		X			X	X	X		X	X	
Shaft basis	X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X
Unilateral tolerances for fits	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
Bilateral tolerances for fits		X						X					X	X				
B.S. 164 Limits and Fits			X				X									X		
Newall system																		
Important dimensions expressed as:																		
Limits of size											X	X		X		X		X
Design size and tolerances ...	X	X	X	X	X	X	X	X	X	X					X	X	X	
Basic size and limits of tolerance...			X						X				X	X				
Surface finish symbols $\overline{\text{VVV}}$ ...				X		X			X									
Surface finish symbols f G		X	X			X		X			X	X		X	X			
S.A.A. surface finish symbols ...										X						X		
U.S. surface finish symbols ...	X																	
Tolerances for concentricity, etc. ...	X	X				X					X				X	X		

TABLE 7 FUNCTIONING REQUIREMENT 5K

$C = L_5 - A_2 \pm \frac{1}{2}(\delta l + \delta a)$

Firm No.	Dimensions		Clearance C	Firm No.	Dimensions		Clearance C
	L_5 (Item 5)	A_2 (Item 2)			L_5 (Item 5)	A_2 (Item 2)	
1	1·205 5 ± ·000 5	1·199 75 ± ·000 25	·005 75 ±·000 75	16	1·206 ± ·000 5	1·200 ± ·000 5	·006 ±·001
2	1·205 ± ·001	1·200 5 ± ·000 5	·004 5 ±·001 5	19	1·204 5 ± ·001 5	1·199 ± ·001	·005 5 ±·002 5
3	1·206 ± ·003	1·197 ± ·003	·009 ±·006	21	1·200 0 ±·006 6	1·194 0 ± ·001 2	·006 ±·001 8
4	1·213 ± ·001	1·200 ± ·001	·013 ±·002	23	1·205 ± ·003	1·199 ± ·001	·006 ±·004
6	1·205 ± ·002	1·199 ± ·001	·006 ±·003	25	1·205 5 ± ·000 5	1·199 5 ± ·000 5	·006 ±·001
7	1·207 ± ·001	1·200 ± ·001	·007 ±·002	26	1·203 ± ·001	1·197 ± ·002	·006 ±·003
8	1·200 6 ± ·000 6	1·198 6 ± ·000 6	·002 ±·001 2	28	1·200 5 ± ·000 5	1·198 5 ± ·000 5	·002 ±·001
9	1·206 ± ·002	1·200 ± ·001	·006 ±·003	35	1·207 ± ·001	1·201 ± ·001	·006 ±·002
10	1·201 ± ·001	1·197 ± ·001	·004 ±·002	Work'g Group	1·201 2 ± ·001 2	1·195 7 ± ·001 2	·005 5 ±·002 4
11	1·204 5 ± ·001 5	1·198 5 ± ·001 5	·006 ±·003				

TABLE 8 FUNCTIONING REQUIREMENT 5K *(Continued)*

$C_R = [(L_5 - A_2) - (B_2 - A_7) - K_2 - P_5]$ max. metal

Firm No.	Dimensions (Max. metal)						
	L_5 (Item 5)	A_2 (Item 2)	B_2 (Item 2)	A_7 (Item 7)	K_2 (Item 2)	P_5 (Item 5)	C_R
1	1·205 0	1·200 0	·502 0	·501 5	·000 5	·001	·003
16	1·205 5	1·200 5	·500 5	·500 0	·001	·001 5	·002
25	1·205 0	1·200 0	·500 5	·500 0	·002	·002	·000 5
26	1·202 0	1·199 0	·500 0	·499 6	·000 5	0	·002 1
Working Group	1.200 0	1.196 9	·500 25	·500 0	·001	·001 5	·000 35

TABLE 12

VARIATION IN CONCENTRICITY ETC. TOLERANCES

Dimension	Item 1 Fig. 3	Item 2 Fig. 4	Dimension	Item 5 Fig. 5	Item 6 Fig. 6
H	2/2	2/2	E	—	2/2
K	3/4	3/4	N	3/3	—
L	4/4	4/4	P	4/4	—

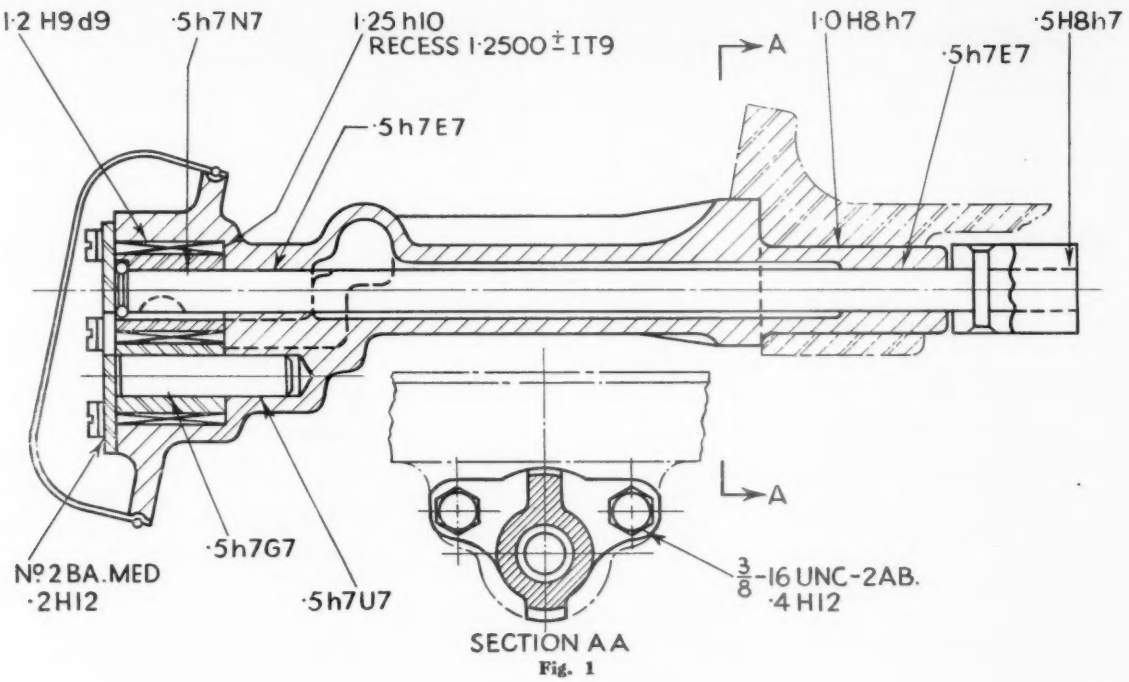

Fig. 1

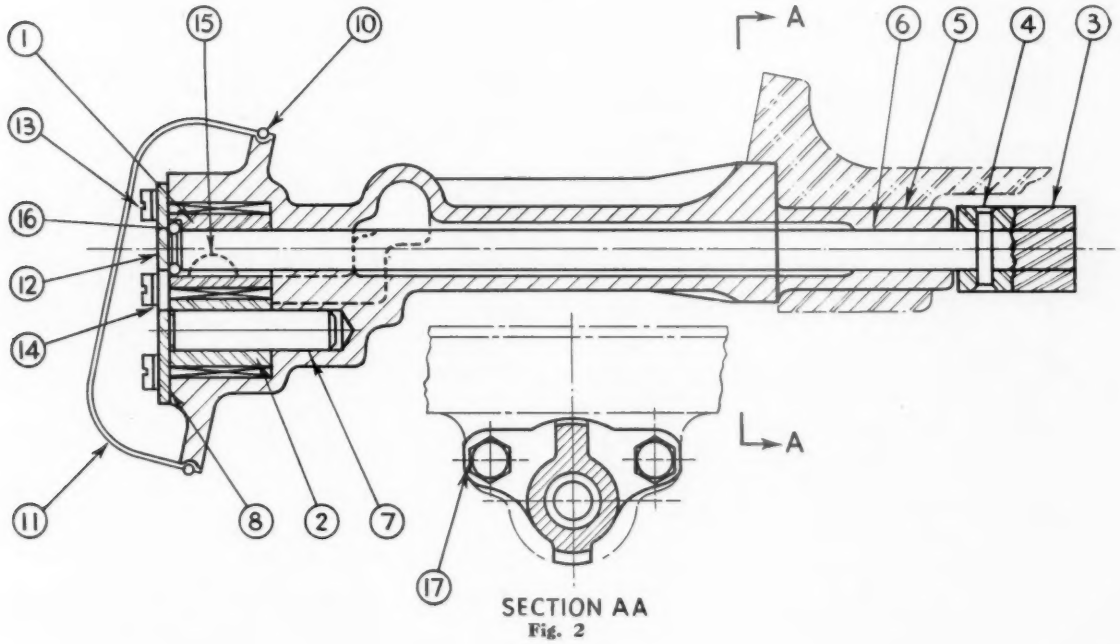

Fig. 2

OIL PUMP

Item	*Description*	*Req'd*	*Drg. No.*
1	Driving Gear	1	OP.01
2	Driven Gear	1	OP.02
16	Circlip	1	OP.16
17	3/8" 16 U.N.C. Hex Bolt	2	OP.17

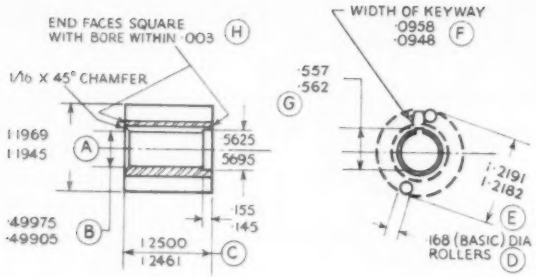

Fig. 3

GEAR DRIVING OIL PUMP

Gear Data

Diametral Pitch	...	10
P.C.D.	...	1.0
No. of Teeth	...	10
Pressure Angle	...	20°
Involute Form		

Concentricity Tolerances (M.M.)

(K) Group 1	Dia. A	...	.001 dia.
	Bore B Datum	...	0
(L) Group 2	Rollers D	...	.001 dia.
	Bore B Datum	...	0

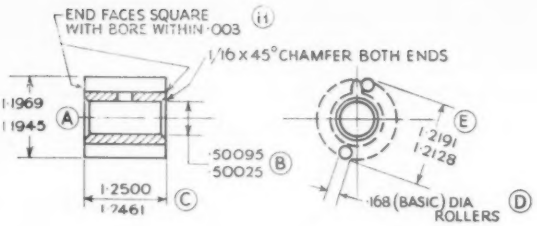
END FACES SQUARE WITH BORE WITHIN ·003 (H)
1/16 X 45° CHAMFER BOTH ENDS
1·1969 1·1945 A
·50095 ·50025 B
1·2500 1·2461 C
1·2191 1·2128 E
168 (BASIC) DIA ROLLERS D

Fig. 4

GEAR DRIVEN OIL PUMP

Gear Data

Diametral Pitch	...	10
P.C.D.	...	1.0
No. of Teeth	...	10
Pressure Angle	...	20°
Involute Form		

Concentricity Tolerances (M.M.)

(K) Group 1	Dia. A	...	.001 dia.
	Bore B Datum	...	0
(L) Group 2	Rollers D	...	.001 dia.
	Bore B Datum	...	0

General Notes

Dimensions are in inches
Sharp corners to be broken .01 rad. max.
Untoleranced dimensions ± IT 14
Finish √ all over
M.M.=Max. metal
Material—mild steel—A.S.(E) D.543

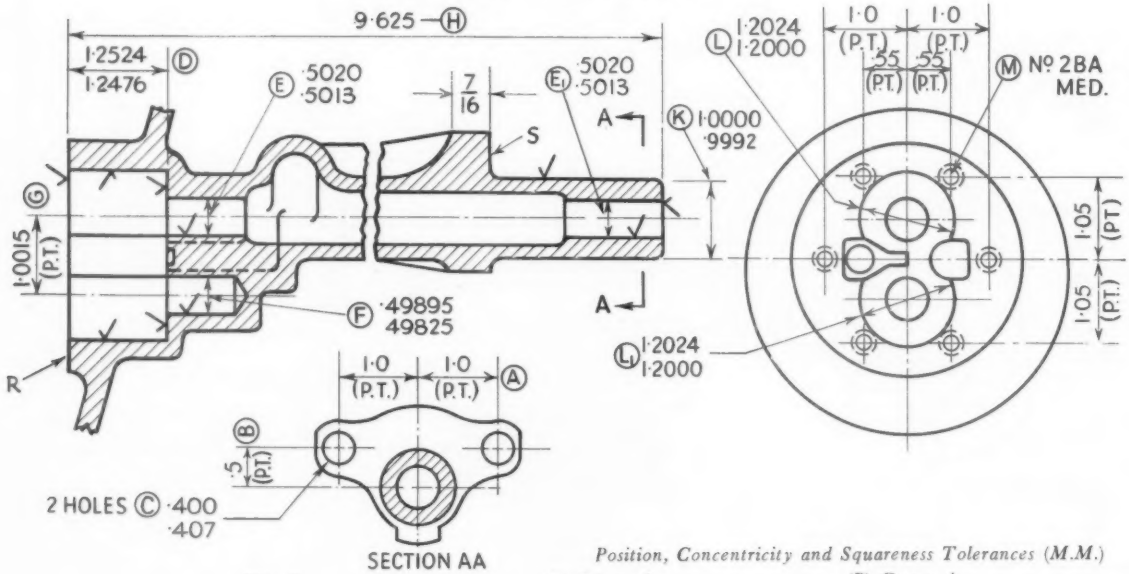

Fig. 5

BODY OIL PUMP

General Notes:

Dimensions are in inches
Sharp edges to be broken (.01 rad. max.)
Untoleranced fractional dimensions ± IT 14
Untoleranced decimal dimensions ± IT 12
√ machined surface
(P.T.) indicates dimensions subject to group position tolerances
Material—cast iron—A.S. B.26 grade "C"
D.=Dia.

Position, Concentricity and Squareness Tolerances (M.M.)

(G) Group 1			
	Hole E	...	.0015D.
	Hole F	...	.0015D.
	Surface R	Datum	0
(N) Group 2			
	Hole E	...	.0005D.
	Hole E	...	.0005D.
(P) Group 3			
	Hole L	...	.0015D.
	Hole E	Datum ...	0
	Surafce R	Datum	0
(P) Group 4			
	Hole L_1	...	.0015D.
	Hole F	Datum ...	0
	Surafce R	Datum	0
(P) Group 5			
	2 holes C	...	.010D.
	Spigot K	Datum	0
	Surface S	Datum	0
(P) Group 6			
	6 screwed holes M.		.008D
	Group 1	Datum	

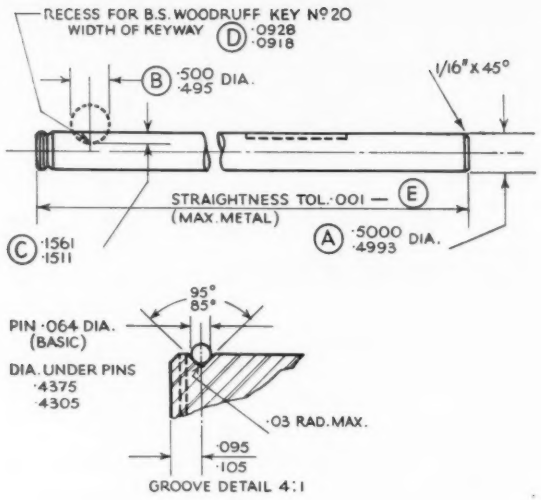

Fig. 6

SHAFT DRIVER OIL PUMP

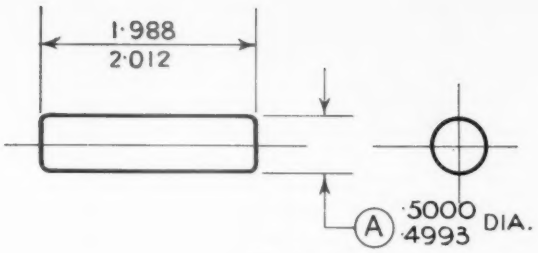

Fig. 7

SHAFT IDLER OIL PUMP

General Notes

Dimensions are in inches
Sharp corners to be broken (.01 rad. max.)
Finish—√ all over
Material—mild steel—A.S.(E) D.543

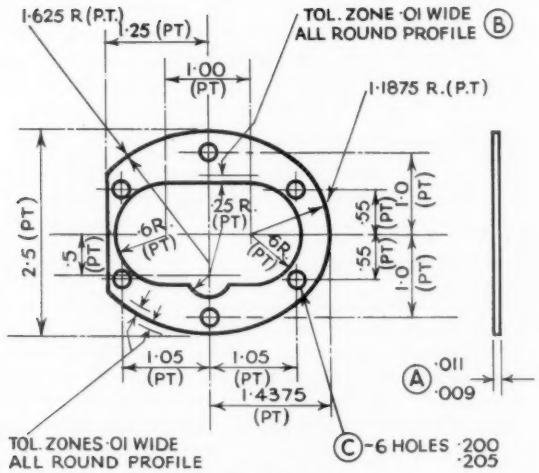

Fig. 8

GASKET OIL PUMP

Position Tolerances (M.M.)

Group 1

6 holes C ... .008D.
Profile B Datum 0

General Notes

Dimensions are in inches
(PT) indicates dimensions subject to group position or profile tolerances
M.M.=Max. metal
D=Dia.
Material—Manilla paper

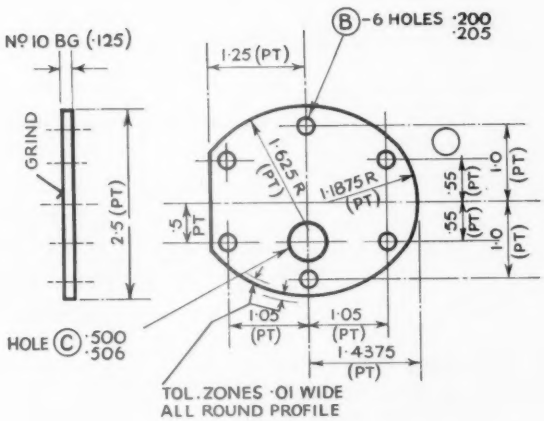

Fig. 9

OIL PUMP COVER

Position Tolerances (M.M.)

Group 1

6 holes B ... .007D.
Hole C ... .015D.

General Notes

Dimensions are in inches
Sharp corners to be broken (.01 rad. max.)
(PT) indicates dimensions subject to group position or profile tolerances
M.M.=Max. metal
D.=Dia.
Material—mild steel—A.S.(E) D.501

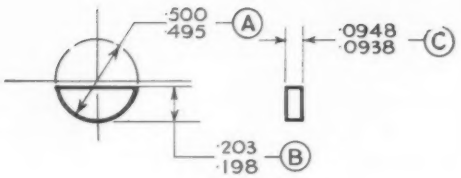

Fig. 10

General Notes
Dimensions are in inches
Finish √ all over
Material—carbon steel—R.S.46

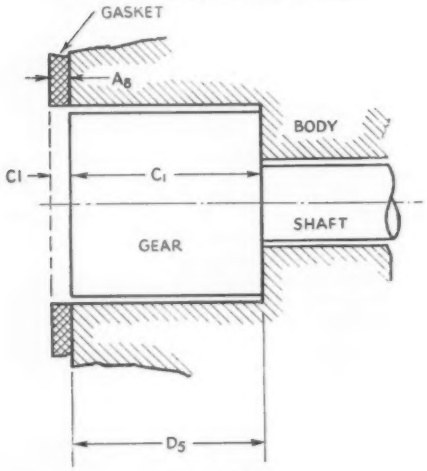

Fig. A1/1

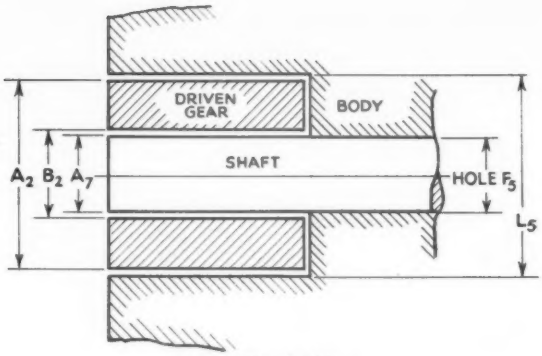

Fig. A1/2

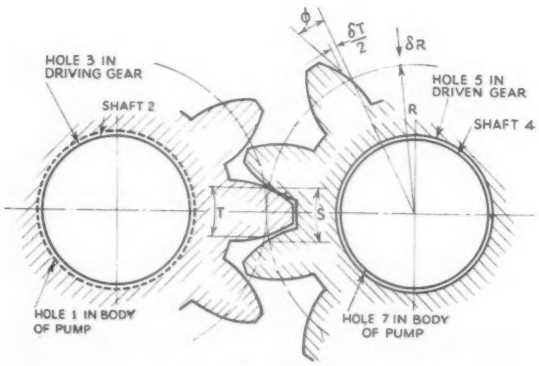

Fig. A1/3

APPENDIX 1

CALCULATIONS FOR FUNCTIONING REQUIREMENTS 5D TO 5N

(All dimensions are in inches)

1. *Functioning Requirement F.R. 5D.*

The working clearance Cl is given by

$$Cl = (D_5 \pm \frac{\delta d}{2}) + (A_8 \pm \frac{\delta a}{2}) - (C_1 \pm \frac{\delta c}{2})$$

where D_5 = mean size for dimension D on Item 5
A_8 = mean size for dimension A on Item 8
and C_1 = mean size for dimension C on Item 1
and δd = tolerance for dimension D on above
δa = tolerance for dimension A above
and δc = tolerance for dimension C above.

Mean $Cl = D_5 + A_8 - C_1$

$D_5 \pm \frac{\delta d}{2} = 1{\cdot}25 \pm$ I.T.9

$= 1{\cdot}25 \pm 0{\cdot}002\ 4$

$A_8 \pm \frac{\delta a}{2} = 0{\cdot}010 \pm$ I.T.9 $= 0{\cdot}010 \pm 0{\cdot}001$

$C_1 \pm \frac{\delta c}{2} = 1{\cdot}25$h10

$= 1{\cdot}2480_5 \pm 0{\cdot}0019_5$

$\therefore$ Mean $Cl = 1{\cdot}2500 + 0{\cdot}0100 - 1{\cdot}2480_5$

$= 0{\cdot}0119_5 = 0{\cdot}0120$ approx.

Max. variation $= \pm \left(\frac{\delta d}{2} + \frac{\delta a}{2} + \frac{\delta c}{2}\right)$

$= \pm (0{\cdot}0024 + 0{\cdot}0010 + 0{\cdot}0019_5)$

$= \pm 0{\cdot}0053_5$

Hence $Cl = 0{\cdot}0119_5 \pm 0{\cdot}0053_5$.

2. *F.R. No. 5(E).*

Fit chosen ·5h7E7

giving hole E_5 . . . ·5020
·5013

and shaft A_6 . . . ·5000 giving C = ·002 ± ·0007
·4993,

3. *F.R. No. 5(F).*

Fit chosen ·5h7.N7
giving hole B_1 . . . ·49975
·49905
and shaft A_6 . . . ·5000, giving I = ·00025 ± ·0007
·4993

4. *F.R. No. 5(G).*

Fit chosen ·5h7.G.7
giving hole B_2 . . . ·50095
·50025
and shaft A_7 . . . ·5000, giving C = ·00095 ± ·0007
·4993

5. *F.R. No. 5(H).*

Fit chosen ·5h7U7
giving hole F_5 . . . ·49895
·49825
and shaft A_7 . . . ·5000, giving I = ·00105 ± ·0007
·4993

6. *F.R. No. 5(K).*

Fit chosen 1·2H9.d9
giving hole L_5 . . . 1·2024
1·2000
and shaft A_2 . . . 1·1969, giving C = ·0055 ± ·0024
1·1945

K_2 = concy. tol. for A_2 with respect to B_2.
P_5 = concy. tol. for L_5 with respect to F_5.

Make all calculations on the maximum metal conditions.*

Then C_R, the clearance between A_2 and L_5 when pump is running, is given by

$C_R = [(L_5 - A_2) - (B_2 - A_7) - K_2 - P_5]$ max metal
= ·0031 − ·00025 − ·001 − ·0015
= ·000 35

* The maximum metal conditions do not theoretically give the worst possible results for C_R but have been taken as the most practical criterion in this instance.

7. *F.R. No. 5(L).*

(*a*) Figure A1/3 shows diagrammatically the two gears in mesh. The backlash measurement is referred to the pitch circles of the gears and is assumed to be equal to the tooth thickness measured along the arc of the pitch circle of one gear minus the corresponding space width measured along the arc of the pitch circle of the other gear.

Shaft 2 is a clearance fit (·5h7E7) in hole 1 in the body and a press fit (·5h7N7) in hole 3 in the driving gear.

Shaft 4 is a clearance fit (·5h7G7) in hole 5 in the idler gear, and a force fit (·5h7U7) in the hole 7 in the pump body.

Let B = backlash measured at the pitch radius.
T = mean gear tooth thickness along arc of pitch radius.
R = pitch radius.
S = mean space width of gear along arc of pitch radius.
φ = pressure angle for gears.
D_1 = mean diameter of hole 1. (E_5).
D_2 = mean diameter of shaft 2. (A_6).
D_3 = mean diameter of hole 3. (B_1).
D_4 = mean diameter of shaft 4. (A_1).
D_5 = mean diameter of hole 5. (B_2) .
D_7 = mean diameter of hole 7. (F_5).
δT = tolerance for T.
δT = tolerance for S.
δ_1 = tolerance for D_1.
δ_2 = tolerance for D_2.
δ_4 = tolerance for D_4.
δ_5 = tolerance for D_5.
p_1 = position tol. for hole 1 in body.
p_7 = position tol. for hole 7 in body.
p_t = concy. tol. for gear teeth in relation to bore.

Referring to Figure A1/3

$\delta T = -2\delta R \tan \varphi$ approx.

where δT is the increase in tooth thickness caused by an increase δR in the radius R.

The negative sign indicates that an increase in R leads to a reduction in tooth thickness.

$$\text{Then } B = \frac{(S \pm \delta S)}{2} - \left(T \pm \frac{\delta T}{2}\right) + \frac{(D_1 - D_4)}{2} 2 \tan \varphi + \frac{(D_5 - D_4)}{2} 2 \tan \varphi \pm 2 \tan \varphi \left[\pm \frac{p_1}{2} \pm \frac{p_7}{2} \pm \frac{p_t}{2} \pm \frac{p_t}{2}\right] \pm 2 \tan \varphi \left[\pm \frac{\delta 1}{4} \pm \frac{\delta 2}{4} \pm \frac{\delta 4}{4} \pm \frac{\delta 5}{4}\right]$$

The last term in the above equation will be neglected as being small in comparison with the other terms.

$$\therefore B = (S - T) + \tan \varphi [(D_1 - D_2) + (D_5 - D_4)] \pm E \text{ approx.}$$

$$\text{where } E = 2 \tan \varphi \left[\pm \frac{p_1}{2} \pm \frac{p_7}{2} \pm \frac{p_t}{2} \pm \frac{p_t}{2}\right] \pm \frac{\delta S}{2} \pm \frac{\delta T}{2} \text{ approx.}$$

$$= \text{Tan } \varphi \left[\pm \frac{p_1}{2} \pm \frac{p_7}{2} \pm \frac{p_t}{2} \pm \frac{p}{2}\right] \pm \frac{\delta S}{2} \pm \frac{\delta T}{2} \text{ approx.}$$

Now let $\delta S = \delta T = ·003$
$p_1 = p_7 = ·0015$
$p_t = ·001$; Tan $\varphi = ·364$
and $S - T = ·003$; $D_1 - D_2 = ·002$; $D_5 - D_4 = ·00095$
hence $B = ·003 + ·364\,(·002 + ·00095) \pm E$
$= ·003 + ·0010_8 \pm E$
$B = ·0041 \pm E$
$E_{max} = ·364\,(·0015 + ·0015 + ·001 + ·001) + ·0015 + ·0015$
$= ·0018_2 + ·003$
$E_{max} = ·0048$
hence $B = ·0041 \pm ·0048$

If centre distance is increased by ·0015
Then reduction in tooth thickness δT
$= ·0015 \times 2 \times \tan \varphi$
$= ·0011.$

With this increase in centre distance **B = ·0052 ± ·0048.**
This should be satisfactory.

(*b*) Some firms toleranced the tooth thickness of the gears indirectly by quoting toleranced dimensions over rollers of specified size. In such cases it was necessary to calculate the corresponding limits for tooth thickness, and the method adopted is described below for the two sizes of roller involved in Table 9.

The relation between roller size and diameter over rollers for the two gears is as follows:

Roller Size	*Basic Diameter over Rollers,* Z_B
·1680 dia.	1·21914 inch
·1728 dia.	1·23445 inch

The above sizes for Z_B were obtained from Machinery's Handbook 1946, (13th Ed'n), p. 854, but may also be calculated by the method of Buckingham and as illustrated in Appendix 2.

The change in the diameter over rollers, δZ, corresponding to a change in tooth thickness δT is given by

$$\delta Z = K\delta T$$

Where K = 2·10 for ·168 dia. rollers,
and K = 2·01 for ·1728 dia. rollers.
The above values for K have also been taken from Machinery's Handbook above.

The basic chord width of the teeth, W_B, is given by

$$W_B = 2 \times \cdot5 \times \sin 9^\circ$$
$$= \cdot1564345 = \cdot1564 \text{ approx.}$$

Hence a diametral measurement of 1·2191 over ·168 dia. rollers corresponds to a chord thickness of ·1564 for the teeth. Also a diametral measurement of 1·2141 over ·168 dia. rollers will correspond to a chord thickness for the teeth of

$$\cdot1564 - \frac{(1\cdot2191 - 1\cdot2141)}{2\cdot10} = \cdot1564 - \cdot0024$$
$$= \cdot1540.$$

Similar calculations can be made in regard to ·1728 dia. rollers.

For the purpose of the analysis shown in Tables 9 and 10, the backlash formula has been rewritten as follows:

$$B = (S-T) + \tan\varphi\ [(D_1-D_2) + (D_5-D_4)] + 2d\tan\varphi \pm E \text{ approx.}$$

where $E = \tan\varphi[\pm p_1 \pm p_7 \pm p_t \pm p_t] \pm \frac{\delta S}{2} \pm \frac{\delta T}{2}$ approx.

and d = difference between the mean centre distance quoted on the drawing and the basic centre distance.

8. *F.R. No.* 5(*N*).

Fit chosen 1·0H8h7

giving hole	1·0013
	1·0000
and shaft	1·0000
	·9992, giving C = ·00105 ± ·00105

APPENDIX 2

CALCULATION FOR DIAMETER MEASUREMENT OVER ROLLERS IN GEAR TEETH

Diametrical Pitch (D.P.) = 10, No. of Teeth (N) = 10.
Pitch Circle Dia. = 1·0 inch.

According to Buckingham, Manual of Gear Design, Section 2,

$$\text{Roller dia.} = \frac{1\cdot68}{\text{D.P.}} = \cdot168$$

Let T_1 = arc tooth thickness at radius r_1
r_1 = given radius
φ_1 = press angle at r_1
φ_2 = press angle at centre of roller
r_2 = radius to centre of roller
X = radius of rollers
M_1 = measurement over rollers
N = no. of teeth in gear.

Then, from Buckingham

$$\text{inv. } \varphi_2 = \frac{T_1}{2r_1} + \text{inv. } \varphi_1 + \frac{X}{r_1\cos\varphi_1} - \frac{\pi}{N}$$

$$M_1 = \frac{2r_1\cos\varphi_1}{\cos\varphi_2} + 2X$$

Basic tooth thickness,

$$T_1 = \frac{\pi}{2DP} = \frac{3\cdot1415926}{2 \times 10} = \cdot15707963$$

r_1 = ·5
φ_1 = 20°.

$$\text{Then inv. } \varphi_2 = \frac{\cdot1570796}{1\cdot0} + \cdot01490438 + \frac{\cdot084}{\cdot5 \times \cdot93969262} - \frac{3\cdot1415926}{10}$$
$$= \cdot1570796 + \cdot01490438 + \cdot1787819 - \cdot31415926$$
$$= \cdot03660662$$
$$\varphi_2 = 26\cdot62088_7^\circ$$
$$M_1 = \frac{1\cdot0 \times \cos 20^\circ}{\cos 26\cdot62088_7^\circ} + \cdot168$$
$$= 1\cdot051121 + \cdot168 = 1\cdot2191$$

Minimum tooth thickness $T_1' = \cdot1570796 - \text{Tolerance}$
$= \cdot1570796 - \cdot003$
$= \cdot1540796$
hence inv. $\varphi'_2 = \cdot03360662$
and $\varphi'_1 = 25\cdot917725^\circ$

Then
$$M'_1 = \frac{1\cdot0 \times \cos 20^\circ}{\cos 25\cdot917725} + \cdot168$$
$$= 1\cdot04477 + \cdot168$$
$$= 1\cdot2128$$

Hence Diameter over rollers is 1·2191
1·2128

APPENDIX 3

ANALYSIS FOR FUNCTIONING REQUIREMENT F.R. 5L ALLOWING FOR PROBABILITY

From Appendix 1, Section 7, and using the same notation, the backlash, B, is given by the expression

$$B = (S-T) + \text{Tan}\,\varphi\,[(D_1-D_2) + (D_5-D_4)] \pm E \text{ approx.}$$

where $E = \pm\frac{\delta S}{2} \pm \frac{\delta T}{2} \pm \tan\varphi\,[p_1+p_7+p_t+p_t]$ approx.

From the mathematical theory of probability the standard deviation for B is equal to the square root of the sum of the squares of the standard deviations for S, T, D, etc.

Let δ_B = standard deviation for frequency distribution for B.

and δ_S = standard deviation for frequency distribution for S.

and so on.

$(\delta_S)^2$ may be written $\mu_s\frac{(\delta_S)^2}{2}$, $(\delta_T)^2$ may be written as $\mu_T\frac{(\delta T)^2}{2}$ and so on, where δS, δT, etc., are the tolerances for S and T, etc., respectively, and hence $\frac{\delta S}{2}$, $\frac{\delta T}{2}$, etc., are the maximum permissible deviations from the mean values of S, T, etc., μ_S, μ_T, etc., are constants depending upon the shape of the distribution curves for S, T, etc.

It is assumed that $\mu_S = \mu_T = \mu_P$, etc. $= \mu = \frac{1}{5}$.

The value of $\frac{1}{5}$ corresponds to a frequency distribution lying somewhere between the rectangular and triangular distributions. This in turn corresponds to fair control over the limits of the appropriate dimensions in the workshop.

Hence $(\delta_B)^2 = \mu\,[\frac{(\delta S)^2}{2} + \frac{(\delta T)^2}{2} + \tan^2\varphi\,(p_1^2 + p_7^2 + p_7^2 + p_t^2 + p_t^2)]$.

Increase tolerances to the following

$\delta S = \delta T = \cdot 004$ inch; $p_1 = p_7 = \cdot 003$ inch

$p_t = \cdot 002$ inch

$B = \cdot 004 + \cdot 0010_8 \pm E$

$= \cdot 0051 \pm E$

$(\delta_B)^2 = \frac{1\times 10^{-6}}{5}\,[4 + 4 + \cdot 364^2(9+9+4+4)]$

$= \frac{1\times 10^{-6}}{5}\,[8+3\cdot 44]$

$= 2\cdot 288\times 10^{-3}$

$\therefore\ \delta_B = \cdot 00151$

and $3\cdot 09\ \delta_B = \cdot 00467 = \cdot 0047$ inch approx.

Hence $B = \cdot 0051 \pm \cdot 0047$ inch.

$\therefore$ Max. $B = \cdot 0098$ inch.

Min. $B = \cdot 0004$ inch.

The distribution for B may be assumed to follow the Gaussian or probability law since B is composed of six independent variables. If the functioning tolerance for B is equal to $3\cdot 09\delta_B$ then only one assembly in 500 is likely to have values for B in excess of that tolerance. Hence only one in 1000 assemblies may be expected to have backlash greater than ·0098 inch and only one in 1000 assemblies may be expected to have backlash less than ·0004 inch.

This would be quite satisfactory in practice.

It should be noted that by taking probability into account as described above, the following percentage increases in tolerances are obtained:

(*a*) Thickness of gear teeth ... ... $33\frac{1}{3}\%$

(*b*) Positions of holes for shafts in body ... 100%

(*c*) Run-out of gear teeth with respect to bore 100%

APPENDIX 4

NOTES ON BS 164 PART I: 1951 (DRAFT) AND BS 308 (DRAFT) REVISIONS OF DIMENSIONING AND TOLERANCE SECTIONS

The standard limits and fits system applies particularly to fits between cylindrical parts, briefly designated as "holes" and "shafts", although the data may be applied in appropriate cases to fits between non-cylindrical parts, "size" referring to a length, width or dimension other than a diameter. B.S. 164, Part I, comprises suitable combination of 16 qualities of tolerance or grades of accuracy of manufacture and 21 grades of fit for both hole and shaft, ranging from fits of extreme interference to those of extreme clearance. Most engineering requirements, from very coarse work to fine gauge manufacture, are covered by this system which covers the size range from .04 to 19.686 inches. A unilateral hole basis is recommended, but a full range of holes suitable for use on a shaft basis system, unilateral or bilateral, is also included in the tables. It is intended that a particular industry or organisation should extract and use those limits which suit its own products; further guidance in the selection of recom-

mended tolerances for a wide range of standard applications is to be published as Part 2 of the Standard.

In order to obtain strict interchangeability between parts made to the ISO Metric System of Limits and Fits and to the equivalent Inch system, the tolerance values have been obtained, not from ISO tolerance formulae, but by direct conversion of metric tolerance values. Both metric and the equivalent inch system tables are given by B.S. 164, the method of compiling the tables being identical with that used in the ISO system, namely:

(i) The 16 fundamental tolerances (called IT1 to IT16) are obtained by converting and rounding the metric values.

(ii) The fundamental limits of tolerance ("A" to "Z" for holes and "a" to "z" for shafts) are also obtained by converting and rounding the metric values.

(iii) The final limits of tolerance are obtained by adding the fundamental tolerances to, or subtracting them from, the fundamental limits of tolerance.

The diameter increments or steps used to subdivide the range of sizes is based partly on preferred (metric) numbers and partly on Continental practice, the direct conversion to convenient inch equivalents being used in the translated Inch tables.

Some recommendations on the choice of fits for ordinary engineering purposes of interference and clearance are given, while, for the convenience of users changing over to the new system, a table relating the ISO fits to the equivalent and probably better known fits of the Newall and B.S. 164:1924 systems appears as an appendix.

Tables of preferred basic sizes are included to obviate indiscriminate selection of dimensions. They consist of one table of binary (or fractional) sizes and another of decimal sizes, the choice of which table to use as standard being left to the user. Each is a series of progressive sizes graded as first, second (or later) "choice" from the point of view of selection as a basic size, the binary table consisting of $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, 1/16, 1/32, 1/64 and multiples, while the decimal series incorporates steps of .05, .1, .2, .5, etc., over the range .01 to 20 inches. The "first choice" values of the binary table are being made the basis for B.S. bearings, oil seals, etc., and should be used for shafts requiring standard bearings and other associated items.

Procedure of using B.S. 164 Limits and Fits may be summarised as:

(1) Selection of a basic size—preferred.

(2) Specifying letter and grade of tolerance for one mating element from the manufacturing process tolerance estimate.

(3) From the functioning requirement desired, a fit is chosen involving the already selected element, thus finding the letter and grade of tolerance required on the mating part.

(4) The values of actual limits of size, for the basic size and selected letter and number grades, are obtained from the B.S. 164 Tolerance tables.

B.S. 308 on "Drawing Office Practice", Sections 12, 13 and 14, ensures a reasonably uniform practice in the expression of drawing dimensions and tolerances, and also provides means of tolerancing such geometrical characteristics as position, squareness, parellelism, straightness, flatness and concentricity. It points out, however, that the whole comprehensive system of tolerancing need not be applied unless the circumstances are such that material advantage will accrue from the increased drawing work entailed.

Sections dealing with the choice of datum for dimensioning, tolerancing practice, dimensions and notes, special features, and the geometrical characteristics above, are included in the Standard. The Specification gives three methods of expressing limiting dimensions and tolerances—

Method A: Specifying directly both limits of size
e.g. 2.5000 2.498
2.5014 2.494

Method B: Specifying one limit of size with a tolerance in one direction only
e.g. 2.5000 2.498
+.0014 —.001

Method C: Specifying desired size with a tolerance disposed above and below the size, not necessarily equal, one may be zero:
e.g. $2.5007 \pm .0007$ $2.4977 \begin{matrix} +.0003 \\ -.0007 \end{matrix}$

Machining and Roughness symbols are also treated in some detail, the "tick" symbol being recommended for the concept "machined surface", where grade, roughness or process are not defined.

The symbol may sometimes be omitted where it is known the surface concerned can only be obtained by machining and where the finish produced by normal processes is acceptable. Where it is necessary to specify the maximum roughness or roughness range that can be permitted, the appropriate roughness number(s) (in micro-inches) is to be placed inside the tick symbol, while the machining process is to be added as a note where the required characteristic of a surface can only be produced by one particular process such as lapping, honing, etc. Provision is made for indication of machining marks "lay" and the roughness assessment "sampling lengths", and a recommendation is made to restrict choice of index numbers to the British Standard B.S. 1134's preferred roughness grades of—

1, 2, 4, 8, 16, 32, 63, 125, 250, 500 and 1,000 micro-inches C.L.A.

CORRIGENDUM

Owing to a printing error, one of the figures quoted in the Paper, "Effective Utilisation of Material", published in the March Journal, is incorrect. On page 176, the figure "118½ lb.", which occurs in the second paragraph, should read "181½ lb.".

SOME PRESENT DAY TRENDS IN ENGINEERING METROLOGY

by C. O. TAYLERSON, M.B.E.,

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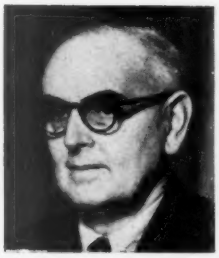
Metrology Division, National Physical Laboratory.



Mr. C. O. Taylerson

An abridged version of the Paper presented to the Coventry Section of the Institution, 20th November, 1952

THE march of progress in engineering metrology has been considerable since the turn of the century. This has been due largely to the impetus of the two intervening World Wars. In both Wars there was a heavy demand for interchangeable parts of a precise nature and mass production of this kind would be quite impossible unless controlled by even more precise measuring techniques. Prior to 1914 engineering measuring equipment available rarely went beyond the hand micrometer or calliper gauge, whereas today there is a seemingly inexhaustible supply of equipment available for making almost any type of measurement that is likely to confront the modern engineer. Such is the progress that has been made.

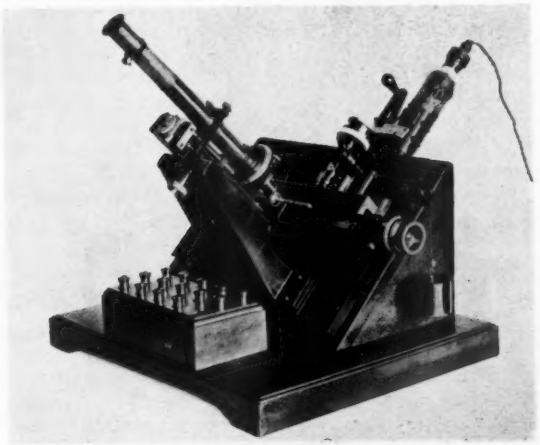


Fig. 1 C.S.I. Bench Microscope for measuring small screws

Optics as an Aid to Measurement

Optical methods of amplification are extensively employed in modern measuring instruments; indeed, this technique is applied nowadays to some machine tools. This is no new departure, as some of the earliest measuring instruments produced, of which the bench microscope (Fig. 1) is an example, made use of optics. Then during the First World War the optical projector (Fig. 2), a British invention, was introduced and developed. There are produced today in many countries countless types of optical projectors for use in engineering metrology. Fig. 3 shows the N.P.L. heavy type projector.

It was during the 1930's that Carl Zeiss of Germany introduced optical methods of amplification to a number of measuring tools and instruments. Zeiss first fitted the reading microscope to these. This meant pioneer work as there was a natural aversion, particularly in the workshop, to the use of the microscope. A typical example was the toolmaker's microscope (Fig. 4). This instrument was an answer to certain limitations of the optical projector. It was not possible on this latter instrument to project, at one setting, an object much greater than about one inch in size. The toolmaker's microscope overcame this limitation. By mounting a microscope, to be used fiducially, over a co-ordinate slide controlled by micrometers set at 90° to each other, objects in one plane up to 4 inches by 2 inches in size could be measured. Other measuring tools to which optical principles were applied followed in quick succession; these included the optical dividing head, the optical rotatable table and the optical protractor.

The immediate effect of the introduction of optics to these tools and instruments was to increase their efficiency and also to enhance their accuracy of

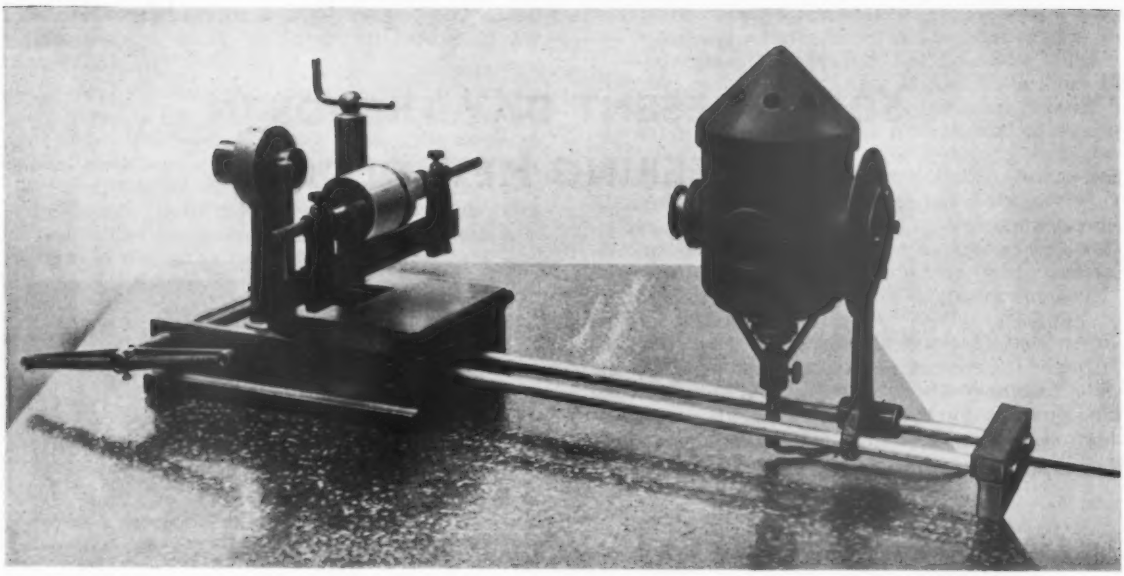


Fig. 2 Early N.P.L. projector

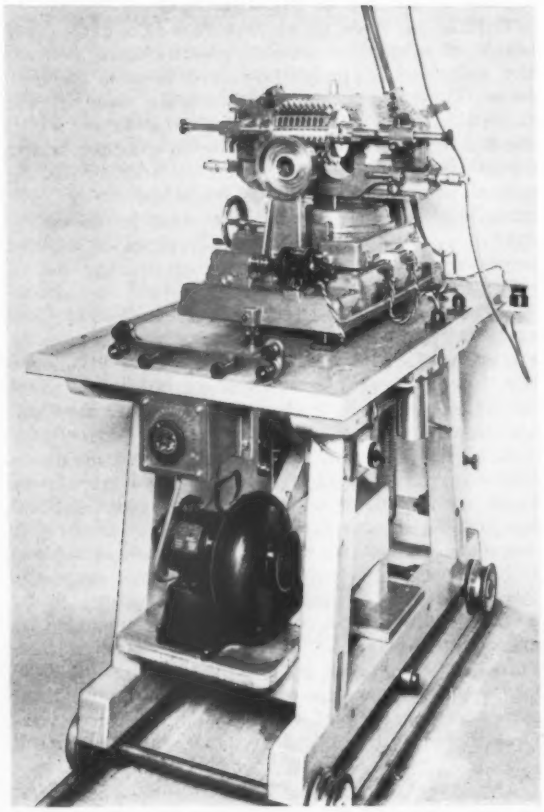


Fig. 3 N.P.L. heavy work projector

measurement. The dividing head is an interesting example in this respect. In its earlier form the accuracy of this measuring tool was dependent on the accuracy of its internal gearing and, because of limitations in the latter, errors in angular measure up to two or more minutes of arc were quite common; furthermore, any subsequent wear on the flanks of the gear teeth would immediately cause a change in the calibration value of the head. With the introduction of optics to this tool, an internal circular glass scale was mounted concentrically with respect to the axis of rotation of the head and

Fig. 4 Zeiss toolmaker's microscope

observed through a microscope fitted to the exterior. In this manner the accuracy of the head was no longer dependent on that of its gearing, the latter being retained merely as a means of rotation, the control of which was obtained by observing the internal glass scale through the exterior microscope. Thus any possible subsequent deterioration in the original accuracy of the head, caused through wear on the gear teeth, was eliminated. In addition, an enhanced accuracy was derived directly from the internally fitted scale, as this could be produced to a much higher degree of accuracy than could the gearing which controlled the accuracy of earlier dividing heads.

This upward trend in the accuracy of measuring tools and instruments had its natural repercussions; for example, new methods of test had to be evolved for checking these higher accuracies. A number of the tools to which reference has been made deal with circular measure. Now the autocollimating telescope, which was developed between the two World Wars, was found to be eminently suited for coping with the higher accuracies in this field. Therefore in consideration of the importance of this instrument in present day metrology and in view of the fact that it is being produced and used in increasing numbers, reference will be made to it in some detail.

The Autocollimating Telescope

The autocollimating telescope, which for brevity is usually referred to as the autocollimator, is an optical instrument designed to measure to a high degree of precision small changes in the inclination of a reflecting surface. Although this instrument is intended primarily for use in making angular measurements it can also be readily employed for making linear measurements, and it is this feature that makes it so valuable a tool in the hands of the metrologist.

It is simple in principle. An illuminated crosswire or graticule is held in the focal plane of an achromatic collimating lens, so that image forming rays emerge beyond the collimating lens in a parallel beam. A reflecting surface held in the path of the parallel rays, and normal to them, will return the image so that it is ultimately brought to a focus in the plane of the object. Small inclinations in the reflecting surface will cause the image to be displaced and the magnitude of this displacement is measured by means of a micrometer microscope. The relationship of this image displacement to the inclination of the reflecting mirror is given by the equation $m = f\theta$ where

m = the displacement of the image as measured in the microscope,

f = the focal length of the collimating lens,

θ = the inclination of the reflecting mirror.

Therefore, from a knowledge of the image displacement and the focal length of the lens, the inclination of the mirror is readily determined. A modern type of autocollimator is illustrated in Fig. 5. In practice, the divisions on the drum of the micrometer microscope are in terms of angular units, so that any change in the microscope reading indicates directly

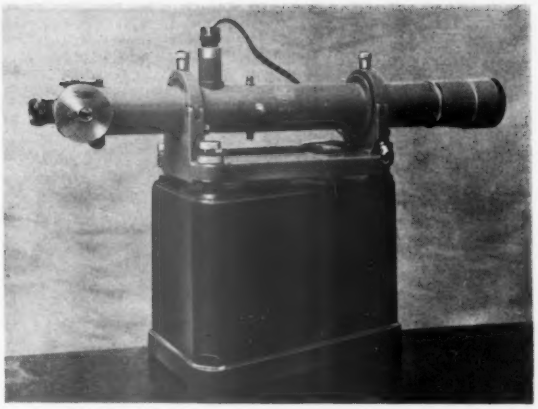


Fig. 5 Watts autocollimator

the change in the inclination of the reflecting mirror. The modern type of autocollimator will read directly to $\frac{1}{2}$ second of arc and, by estimation, to 0.1 second.

The image displacement can be measured in either the horizontal or the vertical plane. This is a valuable feature of the instrument. Among its many uses can be mentioned the checking of the straightness of surfaces in either the horizontal or the vertical plane, the squareness of the end faces of a length bar with respect to its axis, the squareness of a micrometer face to its axis of rotation and the angular calibration of rotating members. For these last measurements the autocollimator has to be used in conjunction with combination angle blocks or polygons—both of which will be referred to in this Paper.

Angle Gauge Blocks

Angle gauge blocks are valuable accessories for use with the autocollimating telescope. A system of combination angle blocks was devised by the late Dr. Tomlinson, of the N.P.L., during the early part of the last War. By means of this system, any required angle can be quickly built by wringing together a few pieces taken from a set of angle blocks. A set consists of twelve angle blocks having wringing faces 3 inches long by $\frac{5}{8}$-inch wide. The system makes use of the fact that angles may be added or subtracted with equal facility and it is this property that makes a small set of only twelve suitably chosen angles so very flexible. The key values of the angles are :

3, 9, 27 seconds.
1, 3, 9, 27 minutes.
1, 3, 9, 27, 41 degrees.

A set of these angle blocks used in conjunction with a precision square block makes it possible to build any desired angle to within $1\frac{1}{2}$ seconds of arc. An example of the building of a combination of angle blocks to give a required angle is as follows :—

Assume a required angle of 37° 21′.

This is obtained by combining the following individual angle blocks

$$27° + 9° + 1° + 27' - 9' + 3'$$

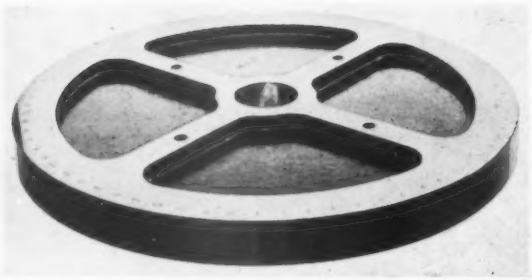


Fig. 6 N.P.L. type 5° polygon (72-sided)

Measuring Polygons

The polygon is a natural development of the angle gauge block and is used, in conjunction with an autocollimator, for checking the precision of rotational movements.

Essentially, the type of precision polygon devised by the N.P.L. consists of a polygonal block of hardened steel having highly lapped side-faces successively inclined to each other by a common angle. This angle may have any convenient value within limits. The most common exterior angle of inclination is 30 degrees, but polygons having exterior angles ranging between 5° and 72° have been manufactured. The limiting factor is the minimum size of the reflecting side face that can be tolerated, having regard to a convenient diameter for the polygon. Fig. 6 illustrates a 72-sided polygon.

Polygons can also be produced satisfactorily in glass, but when glass is employed it is essential that the side faces are treated so as to increase their reflecting powers, otherwise a totally inadequate reflected image will result.

A polygon of first-class finish, used in conjunction with a suitable autocollimator, will permit of angular measurements to within an accuracy of 1 second of arc.

Fig. 7 illustrates the use of a 30° polygon in conjunction with an autocollimator for examining the accuracy of an optical rotatable table. The principle of measurement is self-evident; rotations of the table are being compared directly against the known inclinations of the side-faces of the polygon through the medium of the autocollimator.

Small Angle Generator

It has been shown that rotational calibrations can be made by using known polygons in conjunction with an autocollimator. It could be shown that polygons can be calibrated to a high degree of precision without reference to any exterior standard angle. There still remains the possibility of errors in the autocollimator which, if uncorrected, would give rise to faulty calibrations. It is obviously necessary, therefore, to examine critically the autocollimator for any possible inherent errors. The small angle generator has been designed specially for this purpose. This is illustrated in Fig. 8 with an autocollimator under calibration in position. The generator makes use of the sine-bar principle. A sine-bar arm just over 20 inches in length carries at one end a rigidly held bracket fitted with a small optical mirror. The length of the sine-bar arm can be measured quite easily to the required accuracy. This arm rotates about a pivot in the vicinity of the bracket and a control of its rotation is obtained by inserting slip gauges between a ball contact, attached to the remote end of the sine-bar arm, and a three-ball anvil attached to the main casting of the instrument. Thus angular tilts of the sine-bar arm can be generated to a high degree of precision.

In use, the autocollimator which is being calibrated is mounted on a geometrical support fitted to the main casting of the instrument so as to receive reflections from the face of the optical mirror attached to the sine-bar arm. Thus accurately controlled and known angular movements of the mirror are compared directly against angular changes indicated by the autocollimator and the errors in the latter thereby detected. The accuracy of the generator is ± 0.2 second of arc.

Fig. 7 Calibrating rotatable table using autocollimator and polygon

High Magnification Optical Projector

The optical projector is a well known and extremely useful instrument for examining profiles and shapes that would prove difficult and laborious to measure by ordinary co-ordinate methods.

A projector was recently constructed at the N.P.L. which operates at magnifications ranging between 500 and 1,000 times. This is a special purpose apparatus limited to the projection of small parts where extreme accuracy is required.

One of the uses of this projector is the critical examination of the radii of diamond-tipped penetrators employed in the determination of the hardness of metals.

Application of the Autocollimator to Measuring Instruments

The autocollimator has been used recently at the N.P.L. in the construction of two experimental machines for measuring the internal diameter of plain cylinder bores to a high degree of precision.

Pneumatic Gauging

Gauging by pneumatic methods is no new departure, for it was during the period between the two World Wars that the Solex low pressure pneumatic micrometer was developed. Then, during the last War, General Motors-Holden Ltd. of Australia introduced a high pressure system of pneumatic gauging and this system was further developed at the N.P.L. for inspecting parts produced in large quantities. Since this time, however, there has been a marked increase in the employment of pneumatic gauging in workshops, inspection and standards rooms.

During recent years the principle of pneumatic

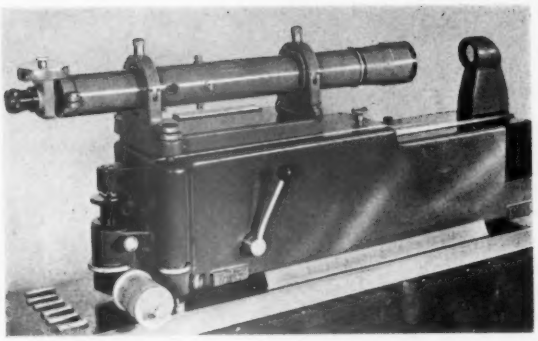


Fig. 8 N.P.L. small angle generator set-up for calibrating an autocollimator

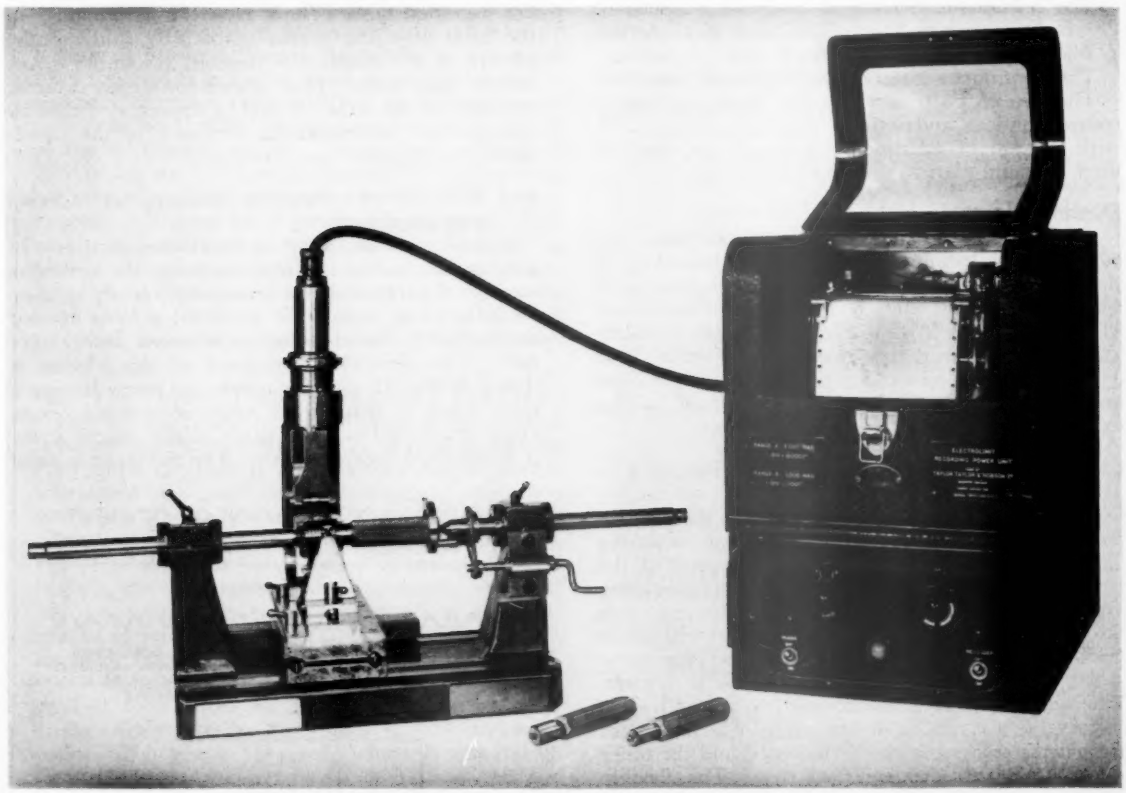


Fig. 9 N.P.L. machine for continuous recording of effective diameter of plug screw gauges

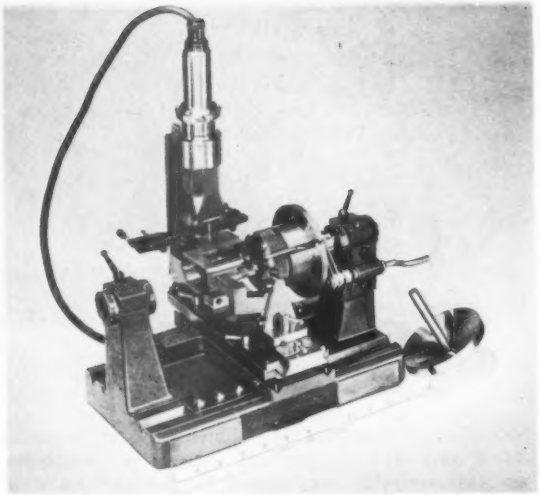


Fig. 10 N.P.L. machine for continuous recording of effective diameter of ring screw gauges

gauging has been applied to measurements in the following spheres :

Assessment of surface finish.

The continuous gauging of fine wire (±0.000 02 inch on wire as fine as 0.001 inch in diameter).

The measurement of small bores.

The continuous measurement of textile materials.

The use of pneumatics is also being applied to control motions and settings on machine tools and, with the aid of additional equipment, it could be used to sound alarms, stop machinery, etc.

Dynamic Metrology

A new term, dynamic metrology, has come into being during recent years. Dynamic metrology is the technique of measuring small variations of a continuous nature. This is a very useful technique, as quite obviously it is much more valuable to obtain a continuous measurement over a surface rather than a few individual measurements at isolated positions on the surface. Brief reference will be made to four examples of dynamic metrology.

(a) *Continuous recording of the effective diameter of a plug screw gauge*

A recent development at the N.P.L. is the production of the continuous effective diameter measuring machine, which incorporates the advantages of the modified version of screw diameter measuring machine for rapid comparative measurements with the additional provision of a graphical record. This machine is illustrated in Fig. 9. Here the plug screw under measurement is mounted between centres. The ordinary micrometer carriage is replaced by one carrying two opposing stylus points which contact the plug screw; one is rigidly mounted and the other is mounted on a flexible steel strip. The flexibly mounted stylus is connected, through a bell crank lever, to a T.T. & H. electrical recorder. The two stylus points are appropriately spaced by half the pitch of the thread under measurement. The plug screw under test is rotated by a small hand crank and variations in diameter are indicated on a graph by the recording unit. To obtain the absolute size, a plug screw of known diameter is first mounted between the machine centres and this provides a datum line on the graph. The screw under test is then mounted between the machine centres and a continuous curve obtained from which size and variation in size can be deduced. The accuracy of repetition possible by this method is ±0.000 03 inch and for absolute size the accuracy is ±0.0001 inch.

This technique has been extended to the measurement of ring screw gauges, and is illustrated in Fig. 10.

(b) *N.P.L. method for obtaining a continuous pitch record of a screw cutting lathe*

This method is illustrated in Fig. 11. A master screw of precise pitch is mounted between the centres of the lathe it is required to test. The thread of this master screw is contacted by a small freely moving wheel mounted in a fitting integral with the lathe-saddle. The lathe is geared to the pitch of the master screw and is set in motion. Any errors in the travel of the saddle will give rise to differential movements between the small contacting wheel and the pitch of the master screw. These small differences are indicated on a T.T. & H. electrical recorder in the form of a continuous graph. By studying the pattern of this graph it is possible to identify errors in the lead screw, gear wheels or other rotating members of the lathe. It will be appreciated that by this method the overall performance of the movements of the lathe can be assessed.

(c) *Method of checking micrometer screws autographically*

Where it is necessary to check the accuracy of micrometer screws in large numbers the orthodox method of calibrating the screws against slip gauges, whilst accurate, is slow. A method has been devised at the N.P.L. for checking such screws autographically. The general arrangement of this scheme is shown in Fig. 12. An accurately cut screw having a pitch equal to that of the micrometer screw serves as the master screw. The pitch of this master screw is determined independently. The micrometer head

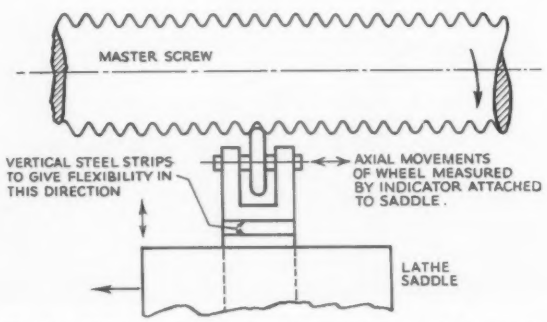

MASTER SCREW
VERTICAL STEEL STRIPS TO GIVE FLEXIBILITY IN THIS DIRECTION
AXIAL MOVEMENTS OF WHEEL MEASURED BY INDICATOR ATTACHED TO SADDLE.
LATHE SADDLE

Fig. 11 N.P.L. method for obtaining continuous pitch record of a screw cutting lathe

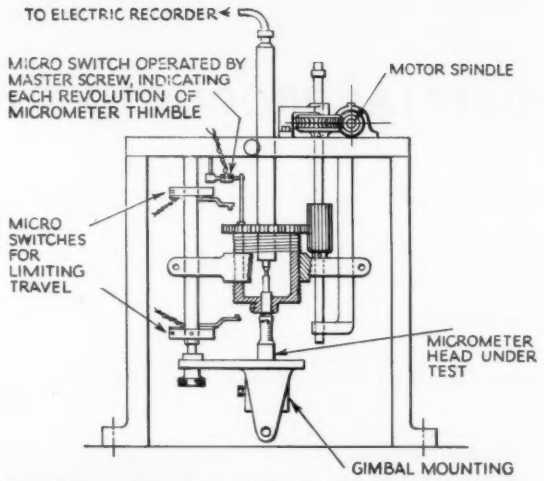

TO ELECTRIC RECORDER
MICRO SWITCH OPERATED BY MASTER SCREW, INDICATING EACH REVOLUTION OF MICROMETER THIMBLE
MOTOR SPINDLE
MICRO SWITCHES FOR LIMITING TRAVEL
MICROMETER HEAD UNDER TEST
GIMBAL MOUNTING

Fig. 12 N.P.L. methodof checking micrometer screws autographically

is clamped to the master screw so that its barrel and therefore its nut rotate integrally with the master screw. The thimble of the micrometer, which is rigidly attached to the micrometer spindle, is prevented from rotating by the frame which supports the nut of the master screw and also an electric measuring head. Although the thimble is prevented from rotating, it is free to move by small amounts in an axial direction corresponding to differences between the axial travel of the master screw and that of the micrometer spindle. These small differential movements are continuously transmitted *via* the electric measuring head to a recorder and finally appear in graphical form on a moving paper strip. This graph is a continuous record of the difference in pitch between the master and micrometer screws. After making allowances on the graph for any known errors in the pitch of the master screw, the pitch errors of the micrometer screw are readily determined.

(d) *The Taylor, Taylor & Hobson "Talyrond"*

One of the most recent additions in the field of dynamic metrology is the Taylor, Taylor & Hobson "Talyrond". This is essentially a single-purpose instrument designed for automatically recording deviations from roundness of internal and external cylindrical surfaces such as balls, rollers, ball races, etc. The object to be measured is placed on, and held to, the work-table of the instrument. An electric displacement indicator is mounted on a vertical spindle of extreme accuracy and is rotated round the inside or outside of the part to be examined. The signal from the indicator is amplified and is then applied to a form of polar co-ordinate recorder giving straight radial ordinates on "Teledeltos" paper. The graph obtained, which is circular in form, shows the amount by which the periphery of the work being tested departs from a true circle. The accuracy of the test is limited only by any residual error in the truth of running of the spindle, which the makers claim is of the order of 0.000003 inch.

A typical example illustrating errors in the circularity of an inner race track magnified radially 4,000 times is shown in Fig. 13.

Conclusion

This lecture has been restricted to a limited field and it mostly refers to work carried out at the N.P.L. Before concluding, however, brief reference should be made to other present day trends in engineering metrology.

There is the introduction of the automatic and semi-automatic multi-gauging machines, specially designed to keep pace with the speed of modern production methods. These machines will inspect parts and sort into as many as six grades at the rate of 10,000 per hour. Some machines will inspect as many as 32 dimensions simultaneously. Of special interest is the Sigma hand operated turret used in conjunction with a comparator for the inspection of up to 10 dimensions on very small parts.

Alignment telescopes are now used extensively in the gauging of aircraft and aircraft jigs.

Modern demands in respect of surface finish have resulted in the design of relatively inexpensive workshop instruments for assessing finish and intended for use by the operator on the production machine.

Finally, the importance of this subject is reflected in the fact that engineering metrology is now included in the Technical College Courses for the Higher National Certificate.

Acknowledgment

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NOTE: *The full text of this Paper is available to members on loan from the Hazleton Memorial Library.*

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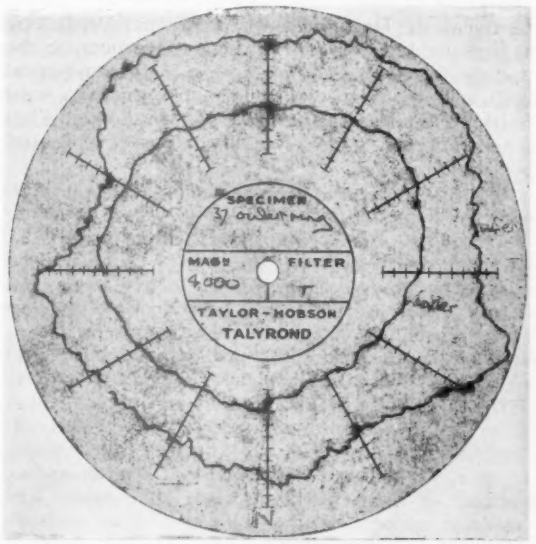

Fig. 13 T.T. & H "Talyrond" record of an inner race track (magnification x 4000)

MANUAL SKILLS AND INDUSTRIAL PRODUCTIVITY

by W. DOUGLAS SEYMOUR

Tube Investments Research Fellow
Department of Engineering Production
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An abridgment of the Paper presented to the Birmingham Section of the Institution, 15th April, 1953.

ALTHOUGH increased mechanisation provides a major contribution to increased productivity, it will be realised that even in the highly mechanised industry of today the key to higher productivity lies often in the skills of individual workers. Whether they are operating the power machines—capstans, presses, sewing machines and so on—which manufacture the components, or whether they are assembling the products of these machines, the operators' " speed skills " are a primary factor in productivity.

Intensive studies of human skills have in recent years proceeded in a number of places, both here, in Europe and in America. In particular mention may be made of the work done, primarily, on the skills employed by Service personnel, at the Psychological Laboratory, Cambridge—work whose value was signalised in 1953 by the Queen's conferment of the Royal Society's Gold Medal on Sir Frederick Bartlett. Relatively little attention has been paid, however, to the specialised field of industrial skills—the skills involved in ordinary repetitive industrial operations. Last year, the Department of Engineering Production at Birmingham University initiated a project for the study of the nature and acquisition of these industrial skills, and the study was helped forward by a most fruitful question posed by Professor Matthew : "What is the difference between performance at a 60 and performance at an 80 "?

In discussing this question, no attempt has been made to define the terms 60 and 80 (which may also be designated " day-work speed " and " piece-work speed "), nor to restrict the consideration of the differences involved merely to these two levels. An attempt has been made, in a broader sense, to consider the changes in human performance on industrial tasks as it improves above the minimum level which could be called adequate in relation to day-work wage, and changes involved in learning a job to such a minimum standard have been ignored. The study of these changes appeared additionally important since it was considered that a better understanding of what happened when an operator improved in performance might indicate better methods of measuring that performance, and of training operators to attain it.

Mr. W. D. Seymour

Traditionally, it is assumed that operators working at piece-work speed exert more " effort " for which they receive greater financial reward, but a consideration of the psycho-physiological factors involved in a quicker completion of a task indicates that increased effort does not wholly account for the difference, nor indeed is it clear what this term means in this context. If the same task is completed by the same method and with the same path of movement of the hands and objects of the tasks, a quicker completion may result from one or more of various factors, such as more effective sensory discrimination, quicker movement of the body members, changes in the organisation in the brain of the receptor and effector processes, etc.

Film Analysis

In order to further our knowledge of the subject, a number of films of actual industrial tasks were examined. These were " rating " films showing scenes of the same operation done in the same way, but at different speeds, and they were edited to provide a uniform basis on which work-study trainees could estimate rate of performance. In analysing these films the movements used in accomplishing the tasks were divided into groups using some of the categories established by Gilbreth and known as " therbligs ". Almost all industrial operations involve picking up objects (" grasp " therbligs), movement of the hand with the object (" transport loaded "), putting the object down (" position "), and moving the empty hand back again for the next object (" transport empty "). An analysis of numerous films showed that, as the rate of performance improved, these parts of the tasks (or therbligs) did not improve proportionately.

Therblig	SLOW No. of Frames	SLOW Average (approx.)	FAST No. of Frames	FAST Average (approx.)
Grasp	16. 14. 14. 14.	14	8. 7. 7. 7. 8. 8. 7.	7
Transport Loaded ...	8. 8. 8. 8.	8	6. 6. 6. 6. 6. 6. 6.	6
Release Load ... ... (Drop marble)	5. 6. 6. 6.	6	3. 5. 4. 4. 4. 4. 4.	4
Transport Empty ...	5. 4. 4. 4.	4	4. 4. 4. 4. 4. 4. 4.	4
TOTAL ...		32		21

TABLE 1. Transport Marble. Time in frames at 16 per second.

One of the first films to be thus analysed frame by frame was made by Professor Mundel of an extremely simple operation, picking up a marble and transporting it a short distance and putting it down into a small trough. This operation is filmed on what is known as the "multi-image-loop", because each frame of the film contains twelve views of the operation and so during the same projection a number of different speeds of performance can be observed together. It is not necessary to quote more than one comparison from this film and, in this case, a comparison is between a performance at somewhat less than sixty (day-work speed) with one at somewhat more than eighty, i.e. the ratio is nearly two to one, not three to four. In the analysis we have segregated the therbligs of transport empty, transport loaded, grasp and release load and the figures for these therbligs (or parts of the task) are given in Table 1.

The following points may be noted:—

(i) The transport empty therblig remains almost unchanged when total time is reduced.

(ii) The release load therblig is considerably reduced, i.e. by some 33% when the total time is reduced to 2/3.

(iii) The transport loaded therblig is only slightly reduced by some 25%.

(iv) The pick up or grasp therblig is decreased by 50% amounting to nearly 70% of the total decrease made.

Results from another study, this time of collating papers, may also be quoted from a film made for the American Society for the Advancement of Management. In this particular film, the scenes representing 60 and 80 performances do not show the operation in sufficiently clear detail for our analysis and the ratio between fast and slow is rather greater as will be seen from the overall times of the cycles shown in Table 2.

It will be noted that:—

(a) The transport empty therblig is again fairly constant over a very wide range of performance —on intermediate performance it was, where recognisable, of the same order.

(b) The grasp therblig varies greatly and by about the same percentage as in the case of the multi-image loop film above. (This of course is accidental since percentages are affected by the proportion of grasp time to total time.)

(c) The handling element involved in placing aside the papers ("position") accounted for the greater bulk of the total time difference.

Other operations which have been analysed in the same way are Pack Cans (S.A.M. film); Dink Squares (S.A.M. film). In these cases the same general pattern has been observed, namely that as the speed of performance is increased the individual therbligs do not improve consistently but "stationary" therbligs, such as grasp and position, improve most, transport loaded improves a little and transport empty changes least.

	Cycle	Cycle Length	Tr. Empty	Grasp	Position
SLOW	1	172	8	6	48
	2	165	8	6	40
	3	159	9	6	35
	4	166	9	6	35
FAST	1	94	9	4	30
	2	93	8	3	29
	3	115	9	5	39
	4	92 (incomplete)	8*	4*	—

* not clear on film.

TABLE 2. Collate Papers. Time in frames at 16 per second.

Therblig	SLOW				MEDIUM				FAST			
Grasp	8.	10.	10.	9.	8.	7.	6.	5.	2.	3.	2.	2.
Transport Loaded	30.	27.	29.	27.	24.	23.	25.	23.	17.	17.	18.	17.
Position	10.	11.	10.	9.	6.	5.	5.	6.	2.	2.	2.	1.
Transport Empty	10.	11.	11.	12.	11.	12.	11.	12.	10.	10.	10.	10.
TOTAL ...	58.	59.	60.	57.	49.	47.	47.	46.	31.	32.	32.	30.

TABLE 3. Transport Cases of Soap. Time in frames at 16 per second.

A rather different type of operation is represented in another film—transporting heavy cases of soap. Here again the therbligs do not change consistently, and a similar general pattern emerges. The times (in frames at 16 a second) for several cycles from each of three different levels of performance are given in Table 3.

An Assembly Operation—Preliminary Experiment

In order to investigate this matter further, it was decided to experiment with a very simple operation of picking up components from a hopper, transporting them to a jig and locating them in a position. In order to avoid the complications of bi-manual coordination, this was done single-handed with the right hand for all subjects. The time measurements were effected by passing a weak current of electricity through the body of the operator; when the component was picked up the current passed from the fingers through the components to the hopper to make one circuit; and similarly through the components and the jig to complete another circuit when they were positioned. By means of valve amplifier the current from these circuits operated pens on a recorder tape so that the time for each therblig was recorded. The apparatus is shown in Fig. 1.

Studies of this very simple operation have been made so far on three subjects with the purpose of observing what change occurs in these therbligs—i.e. grasp, transport loaded, position, transport empty—as the speed of performance in assembling five components into the jig improves. The starting performances of different subjects were, of course, markedly different and the length of practice period necessary to enable them to attain an 80 varied considerably. No special methods were used to help them to attain an 80 performance, but strict supervision of the experiment ensured as far as possible a consistent method was employed (though a departure from this is noted below).

The times for the four therbligs which totalled, in their early attempts, the figure which was assessed at a 60, and in the later attempts those that totalled the figure assessed as 80 performance, have been extracted and are shown in Table 4. In the case of Subject J the early recordings were unfortunately spoilt and there is none extant at 60, but as he progressed to a higher standard than the other two, figures for his performances at approximately 70 and 95 are given.

It will be seen from the table that the therbligs do not improve uniformly, and that the stationary therbligs appear to improve more than the movement therbligs, except in the case of subject 'C'. Here the Transport Loaded therblig improved most but this may have resulted from the fact that this subject started to use thumb and first finger, but changed at an early stage to thumb and second finger, otherwise the latter impeded his movement.

These observations are only preliminary tests which it is hoped will be continued with a full scale experiment, using an electronic timer and recorder which should give more reliable results than the tape recording timer used for these observations.

Discussion of Results

Consideration of the film analyses and of the results of laboratory experiments would lead us to formulate the hypothesis that in industrial operations higher levels of performance in accomplishing a manual task result, not so much from faster hand movements, as from shorter stationary pauses between

Fig. 1

hand movements. This may perhaps be exemplified by an analogy. We often say that under appropriate emotional conditions our heart beats faster; we do not exactly mean that the heart beats faster, but that the intervals between the beats are reduced.

While these investigations were in progress some interesting results were published in America * of experiments using a Motion Analyser, which enabled the total times for series of identical hand movements and of series of manipulations (turning switches) to be recorded.

It was found that travel time (i.e. transport empty) showed relatively very little change as a result of practice, but manipulation time showed considerable decrease with practice.

The study of these films and the observation of operators acquiring speed skills would indicate also that the improvement of performance from a 60 to an 80 results, in part, from the removal of a number of obstacles. First, the obstacle of co-ordination of the two hands is surmounted so that one hand is not unduly held up awaiting the other. Secondly (in many operations) the obstacle of hand and eye co-ordination is surmounted so that hand movements need not be held up awaiting eye fixations. In both these cases the operator is in effect trying to do one thing inside the cycle time of another. Last of all, we come up against perceptual limitations where the problem is the selection, co-ordination and organisation of perceptual information, from the senses, and the limitations of the bodily capacity to carry out the brain's instructions.

Experience in the study of speed skills in industrial tasks and in training operators on factory work indicate, however, that there might be a deeper reason underlining the general and tentative hypothesis stated above. The psycho-physiological basis of human performance in industrial operations has often been overlooked, and a purely mechanistic attitude in interpreting these results is almost certainly inadequate. Human performance on manual tasks in industry—as in other fields of human endeavour—depends upon the perception *via* the senses of "messages" from the task just as much as upon the movements which can be observed in the task itself. Thus, the skill of the watchmaker depends as much upon his ability in fine vision as upon his ability to

* Van Trebra, P.; Smith, K. V. The Dimensional Analysis of Motion: J. Appl. Psychol. 1952. 36-p.348 and 37-4. p.308. AUG. 1953

Subject	Time range	Approx. Equivalent Performance Level	Occurrences	Transport Empty	% Difference	Grasp	% Difference	Transport Loaded	% Difference	Position	% Difference
M.	0.98-1.02	60	7	.257	1%	.210	33%	.322	32%	.221	140%
	0.72-0.78	80	25	.255		.158		.244		.091	
C.	0.98-1.02	60	12	.237	18%	.247	39%	.315	73%	.198	30%
	0.72-0.78	80	14	.200		.178		.182		.153	
J.	8.1-8.8	70	14	.225	10%	.238	55%	.262	37%	.123	45%
	6.1-6.6	95	26	.205		.154		.192		.085	

TIME IN SECONDS (Third decimal place by division; subject to statistical analysis and verification)

Table 4. Therblig Times at Different Levels of Performance

make fine movements with the fingers, and the capstan operator's ability to drill metals of different hardness depends as much upon his discrimination of differences of pressure in the arm muscles as upon his ability to move the star wheel. What is immediately noticeable about the results outlined above is that those therbligs (which happen to be stationary ones) which involve considerable perception improve most with the improvement of overall speed, and that those therbligs which need less sensory perception (which happen to be the movement ones) improve less. In other words the distinction may not be between *stationary* and *movement* therbligs, but between therbligs which involve more perception and those that involve less.

Of course, it would be quite wrong to suggest that there are no perceptual factors operating during the motion therbligs and that all perceptual activity is concerned with the stationary therbligs. Every skilled movement, i.e. every controlled movement, involves the guidance of movement as a result of the continuous reception of information from the body surface or through the eyes and change of muscular activity in conformity with this information. In guiding fine movements, the brain works rather like a governor or control gear, noting at each instant the degree to which the hand has achieved its intention and correcting it for each slight aberration. In other words, the nervous system and the brain operate in skilled performance like a complex servo-mechanism to control the accuracy of bodily activities.

The tentative conclusion outlined above—that therbligs which involve a greater amount of perception are those which improve most with increased performance and those involving less perception are those which improve least—can be regarded another way by looking at it from the point of view of limiting factors. In the early days of industrial studies (i.e. in the days of Gilbreth, Taylor *et alteri*) the limitations on performance were usually physical, because the men they were studying were engaged on heavy physical tasks. Now that modern industrial operations are so simplified, specialised and mechanised the limitations are no longer those of physical strength, physical effort and bodily movement, but those concerned with the brain and nervous system which control the bodily activities. As we all know from experience, when we start to improve any operation we usually improve it in relation to one factor and after a time we find that this is no longer the limiting factor, but some other quite different factor becomes the limiting one—it may be in speeds, or in stresses or in resistances. So in improving the human operator on industrial tasks by training, work simplification, motion study and so on, we have improved various factors until in certain cases we are probably approaching the point at which the limiting factor is no longer an external one, but entirely internal in the operator. But although this factor may now be the limiting one we have not necessarily reached the limits of human performance.

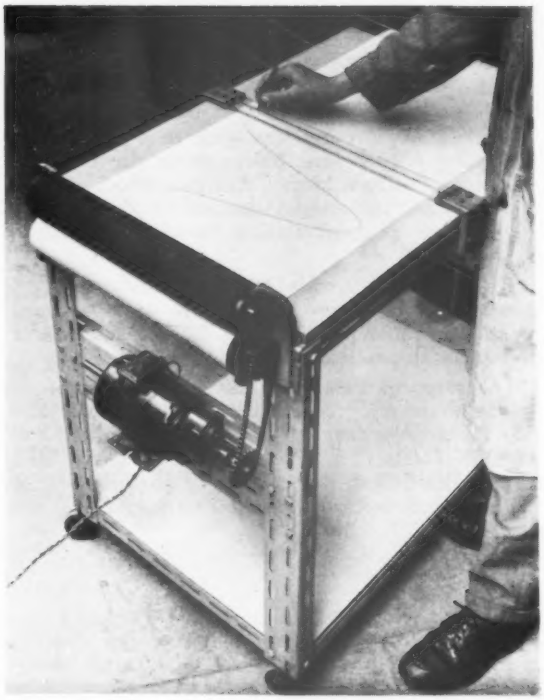

Fig. 2

Perception and Movement Time

So far, we have discussed the relative improvement of stationary and movement therbligs and the relationship of these to the perception involved. It is valuable to consider also the relationship of perception to movement therbligs and the time required to perform them. A further experiment was therefore carried out to investigate the changes in the time taken to perform the same movement with different perceptual requirements. A roll of paper 18″ wide was fitted over motor-driven rollers so that the paper passed over a table at a fixed speed. Subjects were asked to move a pencil point backwards and forwards across this paper as fast as they could freehand, and, owing to the speed of travel of the paper, their backwards and forwards movements gave rise to a wave formation on the paper. The limits of these wave formations were marked—they were almost exactly 16″ apart, and lines were drawn at this distance at the top and bottom of the paper roll. The subject was then asked to repeat his movements but this time to turn exactly on the given lines. Next, a second line was added at the top and bottom $\frac{1}{2}$″ from the existing line and in this case the subject was asked to repeat the performance, again going as fast as he could, but this time to move over the inner line but not over the outer line. Next, a groove 16″ long was fixed over the track of the paper and this time the subject was asked to move the pencil as fast as possible backwards and forwards between the

stops. Lastly, a special pencil was provided which was fitted with a small light. When a moderate amount of pressure was exerted on the pencil this light came on, if too much pressure was applied the light went out again. With this instrument the subject was asked to repeat the operation and to maintain always just sufficient pressure to ensure that the light remained on. The purpose of this experiment, as will readily be seen, was to change the perceptual "load" involved in a movement while at the same time keeping constant the spatial characteristics of movement itself. Throughout the experiment the subjects stood in the same position, held their arms in the same way, made the movements over the same distances and in the same manner, but of course there was a great variation in what they had to do during the movement, in other words in the amount of "information" which had to be taken in and "instructions" which had to be given to the hand in order to control the movement.

Observations

Observations in this experiment, which is illustrated in Fig. 2, were as follows :—

TABLE 5

Number of movements across paper roll (16 inches) in 10 seconds :—

Subject	*A.*	*B.*	*C.*	*J.*	*K.*	*L.*
Freehand	25	22	20	29	18	26
Between stops	24	19	17	25	13	34
Between single lines	16	15	10	9	8	10
Between double lines	16	13	10	10	9	12
Pen light between stops ...	11	—	—	5	4	7
Pen light between double lines	9	5	—	4	1	6
Pen light freehand	7	5	7	3	3	8

It would appear from these figures that the time taken for a movement of constant length can be affected very markedly by the perception which is involved in it. Movements which are constant in length and direction do not therefore require a constant time for their completion—the time is affected just as much by what occurs in the operator during the movement as by the distances which the movement covers. This leads to the formulation of the next hypothesis, namely, that in measuring manual movements attention must be paid as much to the perception involved in movements as to the distance traversed. In other words, the time required for manual movements in industrial tasks appears to depend as much upon their perceptual as upon their spatial characteristics.

The Measurement of Perception

Even if it can be demonstrated that the perceptual component in the skilled performance of industrial tasks has an important effect on the time required for bodily movements, this will be of little practical use in the factory unless we can measure the perception involved. In our considerations no attempt has been made to measure the degree of perception involved; the only distinction which has been made is between movements in which perception (or amount of control activity *or* amount of information from the task to be coped with) is manifestly different from that in others. We have to consider therefore what possible method of measuring perception may be devised. There comes immediately to mind the possibility of employing the concepts of Information Theory for this purpose. Information theory (or communication theory) is concerned with the way in which information passes in communication systems and, correspondingly, in the physiological field, with the way in which sensory information passes from the senses to the brain and the way in which this information is dealt with in the brain and there gives rise to the neural impulses which are the cause of body-member movements. Information theory also is concerned with the brain activities for control, i.e. the way in which precision of movement is affected by small activities to correct errors, these activities being themselves the resultants of the information received from the senses about the degree of incorrectness of previous movements. There is no opportunity here to discuss this fascinating theory, but its importance to our present discussion lies in the fact that information theorists have developed a measure for information and it may be possible to use this unit of measurement as a basis for measuring the perception which is involved in various elementary manual tasks. This unit of measurement is known as a BIT of information, the term being an abbreviation of *Binary digit*.* If it is possible for us to make use of this theory and to use this form of measurement for measuring perception, then many of the problems connected with the measurement in human terms of operators' tasks may come within the range of practical politics. At the moment, these matters remain in the realm of speculation and some years of study will probably be required before we can harness information theory to our industrial problems as a basis for measurement of perception.

The Implications of Perceptual Load in Work Study Techniques

We have stressed the importance of the recognition of perception in the skilled performance of industrial tasks, and the implications of such recognition in relation to the techniques of work study used by the production engineer are worthy of some attention :—

(a) ***Work Measurement.*** Work measurement is probably the most commonly used of those techniques which come under the general heading of Work Study. Most work measurement procedures involve two forms of basic data, namely, the observations of the time taken to accomplish an element of a task and, secondly, an assessment of the rate of performance of the operator in accomplishing the particular element. The subject matter of our discussions affects

* A "bit" of information is the amount of information given or amount of doubt removed when a decision is made between two equally probable alternatives.

very little the former of these two bases but does have bearing on the second, namely, the assessment of rate of working.

Experienced work measurement technicians vary somewhat in their way of assessing the rate of working. Some say that they concentrate their attention on estimating the "overall" flat rate. Some concentrate on the speed of movement. Others say they concentrate on the rate of acceleration of the hand or other moving body member. In our detailed observations in film analyses and in our experiments we have seen, however, that as the rate of performance improves the stationary and movement therbligs do not improve correspondingly. This would lead us to ask, what are the most important therbligs to concentrate on in assessing the rate of performance of an operator? We have seen for instance that transport empty changes less than most of the stationary therbligs and transport loaded tends to vary less than some of the stationary therbligs and this would lead us to the tentative view that in rating the performance of an operator we might do well to concentrate less upon the movements and more upon what is happening in the stationary periods. In the 60—80 range (i.e where we are most interested in rating) where the transport empty therblig is fairly constant, we can perhaps look for a more objective measurement for rating of performance by considering the change in stationary therbligs, i.e. grasp, position, etc. In many cases, these stationary therbligs can be timed quite conveniently by electrical methods and their relationship may provide a better measure of skilled performance than does overall time. In other words, it would appear likely that our assessment of performance might be improved if we attended to those parts of performance which improve most rather than to those which improve least with increased skill.

Such considerations, however, although they might lead us to greater precision in the assessment of relative performances, would still leave these assessments and the work measurement based upon them as a relative matter, i.e. such measurements would have no objective frame of reference. But the quest for an objective basis for work measurement is a very fundamental one in which all work study experts from Taylor onwards have to some extent been engaged. Do our present observations give us any clue as to how an objective measurement of human work can be attained? This probably will only be attainable if we can avoid subjective assessments of performance and substitute for them a measure of the activities which must occur in the human being to accomplish each element or a therblig of a task. We have seen that, for instance, the spatial measurement of a movement gives us no sure indication of the time required for it nor, one would hazard, of the "work" involved in it: but if we can measure not only the spatial movement involved in a task but also the perception involved in each therblig of it, we might possibly in the future be able to arrive on the one hand at an objective measure of the human activity involved and likewise at the ultimate irreducible limit of time in which it can be accomplished. For just as our information theorists can measure some forms of perception for us in terms of "BITS" so they have found that there is an irreducible minimum required for the human brain and body to cope with each BIT of information. This speculation leads us to ask whether it might not be possible, perhaps within the next decade, to measure the work in industrial repetitive operations in terms of the BITS of information involved in their accomplishment and in terms of the irreducible minimum time in which a human being can accomplish them. For certain simple tasks the time taken to perform them can be predicted by the use of information theory, on the assumption that the rate of gain of information for any part of the task is constant. If this form of prediction can be extended, there is promise that ultimately the relationship of actual observed time to this irreducible minimum could provide us with a form of measurement against an objective standard.

(b) ***Motion Study and Ergonomics.*** Since the days of Frank Gilbreth enormous benefits have accrued from the use of motion study techniques and work simplification in industry. Similarly, that branch of these studies which has come to be called ergonomics is contributing very markedly to the improvement of industrial activities. It is rather surprising to notice how little attention has been paid by motion study experts to the perceptual component in skilled performance, in spite of the fact that several of the experts have themselves been trained psychologists. Leaving aside for the moment the considerations of layout, organisation and so on, the main aim of motion study experts in simplifying work has been to improve the path of movement involved in the accomplishment of a task. As Gilbreth wrote in 1911: "the determination of the path which will result in the greatest economy of *motion* and the greatest increase of output is a subject for the closest investigation and most scientific determination". By concentrating on this aspect—the motion aspect—great benefits have been derived and one wonders sometimes whether we have not in some of our most modern factories attained almost the limit of such improvements. But what of the perceptual component which, as we have seen, plays so important a part in all skilled performance? This has, oddly enough, been very much neglected though its neglect would appear to have been at the root of some of the criticisms which psychologists in times past have made of motion study. We have seen that as performance improves, the improvement of movement therbligs does not contribute the largest benefit, and we might therefore do well to concentrate upon the stationary therbligs and also upon reducing and simplifying the amount of information with which the body and brain have to cope in accomplishing them. Much, of course, has already been done in a practical way to tackle this problem, e.g. by the prepositioning of components for assembly so that the number of variables with which the brain has to cope in the grasp therblig is reduced, and the amount of

information to be received and dealt with by the brain is minimised. This approach to work simplification may in the future yield additional dividends after the "path of movement" has been reduced to its minimum.

(c) ***Pre-determined Motion Times.*** During the past decade, the use of pre-determined motion times (such as those of M.T.M. and Work Factor) has become more common in progressive industries and these pre-determined element times have been used both for work measurement on the factory floor and, even more generally, for estimating at the planning stage the time that will be required for accomplishing prospective tasks. It is stated that these pre-determined element times are based upon an analysis of films in which the same elements or therbligs have occurred. In the Department, however, we have found some difficulty in obtaining agreement between the time for a task as estimated by pre-determined element times and that required when the task was done under carefully controlled conditions in the laboratory. This, in view of our discussions, would seem not unlikely. If, as we have said, the time required for a movement depends just as much upon what happens during the movements as upon its spatial characteristics, then pre-determined element times would only be of use for elements or therbligs, which have the same perceptual as well as the same spatial characteristics as those on which the measurements were originally made. This does in fact very often happen and many of the simple assembly jobs for which pre-determined element times have been used involve a degree of perception very similar to that involved in the tasks which were originally analysed to give the times. In such cases, then, the use of these pre-determined element times is reliable, but if they are to have universal application it would appear necessary to categorise the elements not merely in terms of the spatial characteristics of the movements, but also in terms of the perceptual characteristics. Again, if we can harness the results of information theory to the measurement of perception in industrial tasks this further categorisation of movement should be possible, but until we are in a position to describe therbligs in perceptual as well as spatial terms, pre-determined element times would appear to be reliable only when the perceptual conditions of the task originally analysed and those for which they are being used are similar, and it would appear dangerous to exterpolate these results, so to speak, into situations where the perceptual load is different.

(d) ***Training.*** Although operator training is not, strictly speaking, a part of work study, the relevance of these circumstances to the subject of operator training will be immediately recognised. In such training we aim at building up as rapidly as possible the highest possible level of skill in each individual worker and our observations would lead us to believe that this will be best attained by concentrating just as much, if not more, upon perceptual components in the skills as upon the physical movements involved in carrying out the tasks. We have seen that it is those parts of a job which involve most perception which are capable of most improvement, and so it would seem advantageous to concentrate our training effort on those parts of the task. Experience over many years in the practical task of training operators in a variety of industries has led one to the view that most healthy individuals are capable of making most of the movements which are necessary in ordinary industrial tasks. What so many lack is the ability to recognise the sources of information relevant to the task, to organise this information where it is received in the brain, and from there to control the liberation of the muscular energy which accomplishes the movements. It is upon these aspects of training which we should concentrate in attempting to help workers to achieve that higher rate of output which will benefit them and will benefit industry.

Conventions and Hypotheses

In conclusion, one point must be made quite clear. Some of the observations made, and some of the comments expressed, might possibly give rise to the impression that they were in some sense a criticism of work study techniques as they are at present practised. Any such impression should be immediately banished, *since nothing in this Paper is intended in any form as criticism.* The benefits which we have seen in industry from work study are so great that any possibility of undermining confidence in it should be eradicated immediately. What has been attempted is a brief survey of some factors and some observations by the consideration of which we may be able to refine the techniques of work study, qualify them and increase their range and their precision, and the comments are offered as a possible aid to such constructive improvement. Work study techniques, as generally practised, are based upon a number of conventions—extremely useful conventions—without which we could not get along in modern industry. They are rather like some others which are common place in everyday life; for example, we all use the convention of saying that at the same moment it is the same time in Cambridge as in Belfast—and how incredibly difficult life would be if we did not all accept it! The use of this convention does not blind us to the truth of the situation, nor does it hinder scientific progress in astronomy. So, the use of conventions in work study, which are almost equally useful, need not blind us to the fact that they are conventions, nor hinder us in the scientific pursuit of more precise methods of work measurement, etc.

Lastly, it must be made quite clear that this Paper reports some observations and some suggested explanations; that the facts observed arise from and only from the causes suggested is by no means finally proved and much study will be required to demonstrate these matters beyond reasonable doubt. Progress in studies of this kind proceeds in three stages —through observation, through the formulation of hypotheses, and through the demonstration by carefully designed experiments of the validity of the hypotheses. In the matters we are discussing we are only at the second stage, but it seemed worth while to make mention of them now, so that other workers

in this field might by their own experiments help to verify or to contradict these hypotheses. Still more study will be necessary before the results of this work can be harnessed into practical and feasible techniques which can be used on the shop floor for the benefit of workers and of industry generally.

COMMUNICATION

The following comments on Mr. Seymour's Paper have been received:

From: Mr. R. M. Currie, Head of Work Study Department, Imperial Chemical Industries, Ltd.

The assessment of the effect of increased manual skill, especially to industrial tasks of a repetitive nature, is a very complex problem. The author in his interesting Paper discusses the problem and from his observations has formulated an hypothesis, that a much greater improvement is achieved for basic motions requiring a high degree of perception than in those of spatial nature requiring a lesser degree of perception. The examples quoted, although of a preliminary nature, support this concept. Nevertheless, too much reliance must not be placed on the analysis of films unless the conditions under which they were taken and the purpose are known. Often films are made of the same operator working at different speeds. These are not entirely satisfactory for analysis, as an efficient operator finds difficulty in working at slower speeds and is liable to introduce different methods and unnecessary delays.

It is reasonable to expect the time for a basic motion of high perceptual load to decrease as an operator's ability in performing it increases. This ability would depend on the personal aptitude of the operator and the opportunity he is given to develop this ability based on his aptitude. The measure of opportunity depends on the conditions under which the basic motion must be performed, this being maximal when the task contains few different basic motions. It is interesting to note that an example of different degrees of aptitude appears in the experiment the results of which are quoted in Table 4. It will be seen that of operators M and C, although both accomplish the task at the same assessed performance, M is quicker at "grasp" and "position" than C, who is quicker at "transport empty" and "transport loaded". It would, therefore, appear that some means of assessing aptitude as well as perception is necessary unless some connecting link between these can be ascertained.

In discussing the results of the experiment the author is not quite correct in saying the improvement from 60 to 80 rating results in the co-ordination of the hands and the hand and eye. These are two obstacles which should have been removed when the original method was devised, because rating assessment is based on the best known method which must be followed by an operator to obtain a 60 rating otherwise his work would be ineffective. An improvement is gained by a worker attaining greater speed and effectiveness than an average worker suited and accustomed to the particular work; in fact, attaining a greater degree of perception.

Work Study specialists are fully cognisant of the limitations of Work Measurement and are continually striving to obtain means by which the techniques at present practised could be improved. If a greater measure of perception could be gained, then their task would be considerably lightened and a greater degree of accuracy attained. Such an objective is worthy of research, but an assessment of the degree of application of the ultimate result is very necessary, especially as this may be limited to purely repetitive tasks. Another important point is that the ultimate result must be capable of simple explanation to the worker. Its application eventually will affect the worker's pay packet and possibly his reputation. Therefore it is important he should know by what means his work is assessed.

The great benefits of Work Study already achieved could be considerably increased if the techniques are correctly and conscientiously applied to a wider field. This should be the short term policy whilst research is being carried out to improve the techniques. The follow-up of the various observations when confirmed will in fact be the application of Work Study. The improvement of the techniques of Work Study when achieved will mean more effective use of Work Study staff and man-power.

BRITISH STANDARDS

The following Standards have recently been issued and may be obtained, post free, at the prices stated, from the British Standards Institution, British Standards House, 2, Park Street, London, W.1:-

B.S. 806 : 1954	Ferrous pipes and piping installations for and in connection with land boilers. (10/6)
B.S.2078 : 1954	Crates for cabbage lettuces. (2/-)
B.S. 907 : 1954	Dial gauges for linear measurement (excluding lever type). (3/-)
B.S. 308 : 1953	Engineering drawing practice. (10/6)
B.S.2059 : 1953	Straight-sided splines and serrations. (12/6)
B.S.2064 : 1953	Dimensions of diamond abrasive wheels and tools. (4/-)

ELECTRICAL POWER CONVENTION

The promotion of the development of the home and overseas markets for electricity and electrical appliances is to be the theme of the sixth British Electrical Power Convention, which is to be held at Eastbourne from 14th/18th June, 1954. Delegates from 37 electrical organisations from all parts of Great Britain, Northern Ireland, Isle of Man and the Channel Islands will meet under the presidency of Mr. J. R. Beard, C.B.E., who represents the Association of Consulting Engineers.

Associated with the Convention will be an electrical exhibition, staged in the Winter Garden grounds.

INSTITUTION NOTES

PRESIDENT TO SPEAK AT ELECTRONICS CONVENTION

The President of the Institution, Sir Walter Puckey, has been invited to open the Final Session of the 1954 Brit.I.R.E. Industrial Electronics Convention.

During the Convention, which is being held in Christ Church, University of Oxford, from 9th/12th July, over thirty Papers will be presented in six sessions, which include "Industrial Application of Electronic Computors", "Electronic Methods of Testing" and "Electronic Control". Full particulars may be obtained on application to The Secretary, The British Institution of Radio Engineers, 9, Bedford Square, London, W.C.1.

APPOINTMENT OF EDUCATION OFFICER

The Institution is pleased to announce the appointment of Mr. H. Wyndham Badger, M.A., as Education Officer.

Mr. H. Wyndham Badger

Mr. Badger, who commenced his duties on 29th March last, has been for the past three years, Borough Education Officer at Wallsend-on-Tyne, and a great deal of his work in that office was concerned with securing co-operation between industry and local education authorities, in order to develop practical efficiency and to assist school-leavers in their choice of career.

After completing his early education at Wolverhampton Grammar School, Mr. Badger obtained the Board of Education Teaching Certificate and later obtained his B.A. degree at Oxford. He then took the M.Ed (Part I) degree at Manchester University and subsequently obtained his M.A.(Oxon).

During the Second World War, Mr. Badger served in the Royal Air Force with the rank of Wing-Commander. His duties included the direction of operational services for air reinforcements. On demobilisation he was appointed Divisional Education Officer for Kent, and later Chief Officer responsible for the administration of education in South-West Staffordshire.

In 1947, Mr. Badger was appointed Senior Operations Officer with the Ministry of Civil Aviation, where he was in charge of planning and provision of technical services for the United Kingdom and overseas routes. He was Acting Deputy Director at the time of his resignation in 1951 to go to Wallsend-on-Tyne.

CHAIRMAN OF COUNCIL VISITS CANADA AND U.S.

Mr. Harold Burke, Chairman of Council, is at present visiting Canada and the United States, and hopes to meet as many Institution members as possible during his stay in these countries.

REGISTER OF CONSULTING PRODUCTION ENGINEERS

It has been agreed by the Council of the Institution that a Register should be maintained at Head Office of Members who are in practice as Consulting Production Engineers.

Members or member firms who wish to be included in this Register should advise the Secretary as soon as possible, giving details of the type of work in which they specialise.

STANDARDISATION

by C. M. HOLLOWAY, M.I.Prod.E.
Chairman of the Institution's Standards Committee

STANDARDISATION and simplification are becoming more and more vital to industry if the United Kingdom is to compete successfully in world markets, and the function of the British Standards Institution is to carry out the necessary investigations into standardisation suggestions received from both firms and individuals.

The Institution of Production Engineers Standards Committee are concerned lest members of the Institution do not fully appreciate the part they can play in this work. I should like to emphasise that one of my Committee's chief responsibilities is to receive standardisation suggestions from members and to pass these on to the British Standards Institution for appropriate action.

The Standards Committee also nominate members to serve on the Technical Committees and Sub-Committees set up by B.S.I. and receive reports on the progress of the work. During the past year 146 members have assisted in this work. No Standard is issued before it has been agreed between producer and consumer, and draft specifications are widely circulated for criticism; when the Standard is published, a copy is received by the Institution and placed in the Library.

The Standards Committee urge members to bear the importance of standardisation constantly in mind. Comments on existing Standards or suggestions for new Standards will receive the careful consideration of the Committee and, where applicable, will be forwarded to the B.S.I. for necessary action.

Some of the members and guests who attended the Dinner.

The Guest of Honour, Sir Shree Ram, chats with the President of the Calcutta Section, Mr. J. Warren Boulton, and Mr. J. Blakiston, President of the Halifax Section.

CALCUTTA SECTION ANNUAL DINNER

The Second Annual Dinner of the Calcutta Section was held at the Great Eastern Hotel on 12th December, 1953, and was attended by a distinguished gathering of members and guests. Among those present were Sir Shree Ram, the Guest of Honour, one of the country's leading industrialists and a member of several Government Committees; Mr. J. Blakiston, President of the Halifax Section, and Mrs. Blakiston; Mr. J. E. Hill, a Vice-President of the Institution; Dr. S. R. Sen Gupta, Principal of the Bengal Engineering College; Dr. T. Sen, Principal of the Engineering and Technology College, Jadavpur; and Sri. B. N. Choudhuri, Chairman of the Bengal Centre of the Institution of Engineers (India). The President of the Calcutta Section, Mr. J. Warren-Boulton, presided.

In his address Sir Shree Ram said he believed that private enterprise had served India very well in the past and could probably serve her much better in the future, but at the same time he urged industrialists to have patience with the Government's nationalisation ventures. The chief worry of the industrialist, he felt, was the conflicting decisions of the various tribunals and adjudications, and here he thought the Government would do well to make definite decisions.

Sir Shree Ram believed strongly that money spent on welfare facilities for workers was the best possible investment—there should be unanimous agreement between labour and capital.

With regard to industry, India was in its infancy and technically a little backward. It was up to the production engineer to raise profitable production of goods, by which the workers would ultimately attain a higher standard of living.

MELBOURNE SECTION ANNUAL DINNER

The Annual Dinner of the Melbourne Section was held at the Victoria Palace Hotel, Melbourne, on 12th November, 1953, when the guest speaker was Mr. Harold Holt, M.P., Minister for Labour and National Service. Mr. H. G. Sutton, President of the Melbourne Section, presided.

In proposing the toast of the Commonwealth, Sir Fred Thorpe, M.C., E.D., M.I.Prod.E., A.M.I.E. (Aust), Director of McPhersons, Ltd., paid tribute to the work of Mr. Holt, and distinguished between the Government's function of dealing with people and the engineer's function of handling machinery. He defined the duty of a production engineer as having to make more, of better quality, at lower cost.

In praise of the work of production engineers during the War, Sir Fred spoke of the difficulties overcome and the rapid adjustments necessary to cope with changing conditions. With the same spirit playing a peacetime role, the future might be viewed with confidence.

Replying on behalf of the Commonwealth Government, Mr. Harold Holt spoke of the need for high productivity. The rapid build-up of Australian industry during the War, when the country found it necessary to fend for herself, threw a great responsibility on to the shoulders of production engineers. Looking back on the post-war period, he spoke of the need for the Government to show confidence, particularly in difficult times, and this confidence now resulted in a brighter outlook. With expanding exports, the difficulties of inflation and the threat of recession in employment could be overcome.

Speaking of the responsibility of the Government to ensure full employment, Mr. Holt said that this

necessarily meant a certain amount of government planning for industry. Co-operation between Government and industry was essential. The former must give industry opportunity to expand, and to keep the demand for goods high by maintaining purchasing power. Management on their part must give efficiency and wise leadership, and organised labour owed loyalty to Australia as a nation.

In the past, Australian industry had suffered from trade unionism, being dominated by one group, whereas unionists should support management free from political influence. There was a great need for the more thoughtful unionist to take a more active part in these matters.

Referring to the resources of Australia, output of primary industry could be increased considerably, likewise exports of all kinds, and both were essential if the population was to be built up. Mr. Holt felt that it was gratifying to know that in the Institution of Production Engineers there were men who were grappling with these problems. He regarded them as key production men, neither capital nor political, but with the skill and leadership to get the best results from the workers.

The Guests

In proposing the toast of "The Guests" Mr. B. G. Ross, Past President, Melbourne Section, said that the Institution was honoured by the attendance of so many eminent industrialists. He paid tribute to Mr. Holt's grasp of industrial problems, due to which time lost through disputes was now less than two hours per worker per annum. Immigration was on a larger scale than in the U.S.A. at any time of an immigration quota, and the high standard of immigrant now entering Australia was a factor in raising the level of knowledge and technical ability available to industry.

Mr. Ross went on to mention several other distinguished guests, and the services they had rendered to Australian industry. Among these were Major General Risson, renowned in his job of organisation of the Melbourne tramways; Professor Henderson, who initiated a course in Production Engineering at the University; Mr. H. B. Breen, of the Department of Defence Production, for production of the Canberra bomber; Mr. C. P. Pusey, for assisting in the development and protection of Australian industry; Mr. O'Laughlan, of the Department of Defence Production, for the production of armaments; Mr. R. H. Lowe, of the Australian Institute of Metals, for co-operating with the Institution of Production Engineers in Working Group meetings; Mr. J. Steer, Director of McPherson's Ltd. and an officer of the Adelaide Section of the Institution, for the part he played in establishing the Institution in Australia; and Mr. John Hill, Director of John Lund & Co. Ltd., Yorkshire, Past President of the Institution in London.

Finally, Mr. Ross spoke of the support of affiliate companies, so valuable to the Institution in the work of raising the standard of efficiency.

Responding to the toast of "The Guests", Major General R. H. Risson, C.B.E., D.S.O., E.D., B.E., M.I.E.(Aust.), M.Inst.T., Chairman of the Melbourne and Metropolitan Tramways Board, thanked the Institution for the very warm welcome extended to the visitors, and suggested that the guests had much in common with the Institution. The Institute of Metals and the Institution of Production Engineers were mainly concerned with advancing the industrial status of the nation, and production engineers had made a great contribution to Australian industry.

Supporting Major Risson on behalf of the guests, Mr. John Hill gave some of his impressions as a visitor from England. In his experience there was very little difference to be found between countries in the English-speaking world. Canada, U.S.A., New Zealand, Australia, all appeared to have the same problems, mainly concerned with increase of production, and making two blades of grass grow where one grew before. The necessity for reducing manufacturing costs in Australia to compete in export markets was very much the same as in England, to meet competition from Japan and Germany.

In conclusion, Mr. Hill gave details of the new premises recently acquired for the headquarters of the Institution of Production Engineers in London, and assured the Melbourne Section that Australian members visiting London would receive a very warm welcome.

FUTURE INSTITUTION ACTIVITIES

In addition to the meetings listed in the Journal Supplement, the attention of members is drawn to the following important events :-

Production Exhibition and Conference, Olympia, London, July 7th/14th, 1954.

"Information and the Production Engineer"—Joint Conference with Aslib Aeronautical and Engineering Groups, College of Aeronautics, Cranfield, 2nd/5th April, 1954.

Full particulars of these Conferences may be obtained on application to the Secretary, 36, Portman Square, London, W.1.

NEWS OF MEMBERS

MR. F. R. W. CHARLTON

The Institution is pleased to record that Mr. F. R. W. Charlton, Associate Member, a member of the Adelaide Section Committee, was included in the New Year's Honours List. He has been awarded the M.B.E. for his services to the Citizen Military Forces.

Since 1937, he has been in the Royal Australian Engineers. During the War he was on active service in the Middle East. He holds the rank of Major and since 1948 has been Officer Commanding, 3rd Field Squadron. Mr. Charlton is Works Superintendent for Horwood Bagshaw Limited.

MR. L. P. COOMBES

Mr. L. P. Coombes, President of the Oxford Section, has been appointed K.D. Engineer to the British Motor Corporation. He joined Morris Motors Ltd. (Cars Branch) in 1941 as Production Superintendent in charge of several wartime projects. In 1943 he became Planning Engineer and took over the newly-formed K.D. Division of the Nuffield Organisation in 1948. Since then he has travelled to Australia, New Zealand, Holland, Eire, and America, to make on-the-spot investigations of individual requirements.

MR. B. A. J. RULE

Mr. B. A. J. Rule, Associate Member, Chief Inspector, The Newall Engineering Co. Ltd., has recently visited Sweden at the invitation of the SKF Company of Gothenburg, in order to study production and inspection at the SKF works of methods employed in the manufacture of components used in Newall machine tools.

MR. T. H. BEARD

The Institution has accepted with great regret the resignation of Mr. Trevelyan H. Beard from the position of Honorary Secretary of the Canadian Section. Mr. Beard has found it necessary to relinquish this work owing to extreme pressure of work and studies. The position of Honorary Secretary to a newly formed Section, particularly when it is so remote from the headquarters of the Institution, is not an easy task, but one which in Mr. Beard's case has been accomplished with marked success. His help and assistance have in no small measure been responsible for bringing the Canadian Section to its present status.

Mr. Beard's successor as Section Honorary Secretary is Mr. P. M. Wood, Graduate.

MR. C. M. P. WILLCOX

Mr. C. M. P. Willcox, Associate Member, has resigned his position as Manager of the Air Cylinder Department of Benton & Stone, Ltd., to rejoin a family concern, P. L. Willcox, Ltd., Tyseley.

Mr. Willcox, who is an active member of the Materials Handling Sub-Committee, is a well-known lecturer, and has addressed Sections of the Institution, and other engineering bodies, in many parts of the country.

MR. J. M. STEER

After many years of service to the Sydney Section, Mr. James M. Steer, Associate Member, was appointed Manager of the Adelaide branch of McPhersons, Limited. He immediately joined the Committee of the Adelaide Section, and for the last two years has given invaluable service to this Section as Secretary, Vice-President, Australian Sub-Council Member and member of the Education Sub-Committee.

Mr. Steer has now been promoted to the Company's headquarters in Melbourne as Director of Machine Tools, and will have control of the sales of the products manufactured by the company, as well as the machine tools from many well-known overseas factories, for which McPhersons have the Australian agencies. Mr. Steer is at present in England, and will spend three months visiting machine tool factories. The Adelaide Section Committee met at a luncheon to thank Mr. Steer for his work for the Section, to wish him a good trip overseas, and success in his new appointment.

VISITOR FROM CANADA

A member of the Institution's Canadian Section, Mr. O. C. Kallay, is at present in the United Kingdom, and has kindly offered to answer, as far as he can, questions from members who are interested in Canada and Canadian affairs.

Mr. Kallay may be contacted at :-

82, Fidlas Road,
Llanishen, Cardiff, Glam.

MR. D. F. HORNE, M.B.E.

Owing to a typographical error, the note concerning Mr. D. F. Horne in the March issue of the Journal stated that he had been appointed to the Board of a Company with the Rand group of manufacturers. Mr. Horne has in fact been appointed to the Board of British Acoustic Films Ltd., within the J. Arthur Rank Organisation Limited.

NEW APPOINTMENTS

Mr. A. B. Brown, Associate Member, has now joined the Board of Brown Bros. & Co. Limited, Rosebank Ironworks, Edinburgh.

Mr. J. W. Browne, Member, was recently appointed Senior Lecturer in Production Engineering in the Engineering Department of the Technical College, Bolton.

Mr. K. H. Buckley, Associate Member, has recently taken up the position of Superintendent in charge of Forwarding and Transport with his Company, The English Electric Co., Stafford.

Mr. L. Carroll, Associate Member, has been appointed Manufacturing Specialist at the Schenectady Works of International General Electric, U.S.A.

Mr. N. E. Cornish, Associate Member, has now taken up an appointment as a Production Engineer with The English Electric Co. Ltd., Luton.

Mr. M. L. Curtis, Member, has just taken up a new appointment as Director and General Manager of Singer Motors Limited, of Birmingham and Coventry.

Mr. L. J. Daughtrey, Associate Member, has recently taken up a position as Production Engineer with Smith-Wilson Engineering Co. Ltd.

Mr. P. J. Gibbons, Associate Member, has recently taken up the position as Manager at The Myers Spindle Co. Ltd., Bradford.

Mr. G. E. H. Hall, Associate Member, is now General Manager of Sheepbridge Stokes Limited, and British Van Der Horst Limited, members of the Sheepbridge Group. Mr. Hall was formerly Works Manager of Light Production Limited, Slough, Bucks, another Sheepbridge Company. Before joining the Sheepbridge Group, Mr. Hall served for nearly seven years with Wellworthy Limited as Assistant Works Manager and Works Manager.

Mr. R. Hunt, Associate Member, has recently been appointed Works Manager of Paton, Calvert & Co. Ltd., Liverpool. Mr. Hunt joined the Company 21 years ago and has held appointments as Head of the Time and Motion Study Department, and Chief Engineer.

Mr. S. C. Jones, Associate Member, has recently accepted a commission with the Royal Canadian Navy as Lieut. Engineer with the appointment as Resident Naval Overseer, Owen Sound, Ontario.

Mr. A. Marsden, Associate Member, has recently been appointed Manager of the Plastics Moulding Plant of Universal Metal Products Limited, Southport.

Mr. A. Leslie Martin, Associate Member, has relinquished his position as Lecturer at the County Technical College, Wednesbury, and has now taken up a position as Head of the Department of Engineering at the Riversdale Technical College, Liverpool.

Mr. Norman Maxfield, Associate Member, has now taken up an appointment as Personal Assistant to the Works Director of Henry Simon (Engineering Works) Limited, of Stockport.

Mr. G. K. E. McCall, Associate Member, has recently been made a Director of Churchill-Redman Limited, Halifax.

Mr. C. M. Moatt, Associate Member, has now been transferred to Admiralty Signals and Radar Establishment, Haslemere (A.S.R.E.).

Mr. A. L. Orchard, Associate Member, has recently taken up an appointment as Works Superintendent with Morphy-Richards Limited.

Mr. F. H. Perkins, Member, has recently relinquished his position with the North British Locomotive Company and has now taken up an appointment as Chief Production Engineer with Brush Electrical Engineering Company, Loughborough.

Mr. G. A. Symons, Associate Member, has now returned from the United States and has taken up the position of Chief Inspector with Diamond H. Switches of Chiswick.

Mr. Y. Tandan, Associate Member, has now taken up an appointment as Manager with Guest, Keen Williams Limited in their Permanent Way Works Department.

Mr. C. H. Viles, Associate Member, has been appointed Manager of the Leeds branch office of Burton, Griffiths & Company Limited, which covers the county of Yorkshire. Mr. Viles was formerly Sales Representative in the area north of the Yorkshire border and in his new capacity will still supervise the counties of Durham and Northumberland.

Mr. Eric Ward, Associate Member, has relinquished his position with Kodak Limited, and has now taken up a position as Assistant Manager of the Production Division, Information and Research Department of the British Institute of Management.

Mr. R. A. G. Welsher, Associate Member, has recently been accepted into the Ministry of Supply Engineers Pool as a Professional Engineer, Basic Grade. Mr. Welsher is retaining his position of Remote Handling Engineer with the Atomic Energy Research Establishment, Harwell.

Mr. P. A. Wibrow, Associate Member, has recently left Adelaide in order to take up a position with the Public Works Department of Her Majesty's Colonial Service in Selangor, Malaya.

Mr. H. C. Wright, Associate Member, has recently taken up an appointment as Production Engineer to the Washington Chemical Co. Limited.

Mr. W. Worsley, Member, has recently taken up a position as Chief Engineer at Colvern (Radio) Limited.

Mr. J. Berkman, Graduate, has been transferred to the Israeli branch of H. H. Fraser & Associates for a special assignment.

Mr. N. J. Bullock, Graduate, has recently taken up a position as Planning Engineer with D. J. Napier & Son.

Mr. R. Cameron, Graduate, has taken up a position as Designer with Joy Sullivan, Mining Machinery Manufacturers.

Mr. J. V. Courtney, Graduate, has recently been appointed Assistant Lecturer at Poplar Technical College.

Mr. G. Cubitt-Smith, Graduate, has been appointed Production Officer at the Chelmsford Works of Crompton Parkinson Limited.

Mr. E. A. Hewitt, Graduate, has now been appointed Plant Engineer of Paton, Calvert & Co. Ltd.

NEW BUILDING FUND APPEAL

Since the publication of the last list, donations have been received from the following subscribers. (The list was compiled for press on 12th March, 1954.)

G. P. Belsham, M.I.Prod.E.
W. H. Bradford, A.M.I.Prod.E.
V. F. Burgess, Grad.I.Prod.E.

S. R. Chowdhury, Grad.I.Prod.E.

J. G. Dawkes, Grad.I.Prod.E.

N. A. Ferguson, A.I.Prod.E.

G. Gilfillan, M.I.Prod.E.

A. Goodwin, Grad.I.Prod.E.

H. B. Harris, A.M.I.Prod.E.
A. G. Hayek & Partners Limited.
I. G. Hopkinson, M.I.Prod.E.

S. E. Kirk, M.I.Prod.E.

E. G. McLeod, A.M.I.Prod.E.

J. D. Nicholls, A.M.I.Prod.E.

R. S. Odd, M.I.Prod.E.
A. P. Oppenheimer, A.M.I.Prod.E.

S. W. Perkins, M.I.Prod.E.

D. H. Turnbull, M.I.Prod.E.
J. P. Turley

J. R. Wells, Grad.I.Prod.E.
J. Whyte, Grad.I.Prod.E.

PREPARATION OF TECHNICAL REPORTS

A course of four lectures on the preparation of technical reports, commencing on 30th April, 1954, is being arranged by the Department of Electrical Engineering of University College, London, in conjunction with the Regional Advisory Council for Higher Technological Education. The fee for the course, which is intended for engineers in industry, is £1. 1s., with a registration fee of 10/6d.

Full particulars may be obtained from The Secretary, Regional Advisory Council for Higher Technological Education, Tavistock House South, Tavistock Square, London, W.C.1.

MANAGERS IN INDUSTRY

A residential course for managers in industry has been arranged by the University of Cambridge Board of Extra-Mural Studies, and will be held at Madingley Hall, Cambridge, from 28th June to 23rd July, 1954.

The course is designed to throw light on the role of the manager and his personal responsibilities in present-day society. It is proposed to examine the opportunities and responsibilities.

JOURNAL BINDERS

Members are advised that binding cases for the Journal are available, and may be ordered from Head Office. The cases, which are strongly made and covered in dark red leather cloth, with "The Institution of Production Engineers Journal" in gilt on the spine, will each hold 12 copies of the Journal. The price per case is 10/-, post free.

HAZLETON MEMORIAL LIBRARY

Members are asked to note that the Library will normally be open between 10 a.m. and 5.30 p.m., from Monday to Friday each week. The full facilities will not be available at the following times during the month :—

Thursday,	8th April	from 10.0 a.m.	Good Friday,	16th April	all day
Easter Monday,	19th April	all day	Tuesday,	27th April	from 2.15 p.m.
Thursday,	29th April	from 11.0 a.m.			

It would be helpful if, in addition to the title, the author's name and the classification number could be quoted when ordering books.

REVIEWS

621.9 MACHINE TOOLS; MACHINING

" Metal Machining " by Lawrence E. Doyle. *New York, Prentice Hall Inc.,* 1953. 511 *pages. Illustrations. Diagrams.* £4. 0. 0.

A recent article by Patrick Halliday in the " Manchester Guardian ": " Are British Technical Books Good Enough? " makes this point: " It is for junior engineers, technicians, and skilled mechanics seeking to improve their knowledge of modern techniques without the guidance of a teacher that the more academic British books, with their emphasis on close mathematical argument and their apparent remoteness from everyday practice, compare most unfavourably with their transatlantic counterparts."

This book exemplifies the general truth of the statement; it is a well written and produced elementary book covering the most recent and widely used methods of metal machining. The principal types of edge and abrasive cutting machine tools, and their applications in straightforward representative manufacture, are thoroughly treated.

Introductory chapters on dimensioning and tolerancing, measurement and gauging, and the action of cutting tools are well conceived. The remaining chapters, with the exception of those on screw thread production and process planning, are each devoted to a principal machining process, its main types of machines and their applications; e.g. Milling Machines and Cutters, Abrasive Grinding Wheels and Operations, Gears and Gear Making, Turret Lathes and Automatics, etc.

The book has a wealth of photographic illustration which, in the main, considerably enhances its value. Two small criticisms might be made; in a few of these illustrations the detail is not clear—the six spindle automatic (page 486) is a particularly noticeable example; in some instances line diagrams would have been more effective.

The author is to be complimented on a clear, readable text, on the stimulating list of questions and useful references at the end of each chapter, and on the very adequate index. The book is exceptionally well produced and bound.

Unfortunately, its price in this country (80/-) will prevent its reaching many of the readers for whom it is specifically written. A. J. C.

621.777 PROCESSES FOR WORKING SHEET AND PIPE

" Pipe and Tube Bending " by Paul B. Schubert. *New York, Industrial Press,* 1953. 183 *pages. Illustrations. Diagrams.* £2. 2. 0.

Here, at last, is a text-book which clearly sets out all the known methods of pipe and tube bending, particularly for those interested in the lighter branches of engineering. The author has cleverly collated all the information he has gained, both from English and American sources, and to whom he gives full credit, and the whole book is very well illustrated with exceptionally clear photographs and line diagrams which amplify the text even more.

In common with so many books of this nature, which are American in origin, the typescript is very legible and well set out, thus avoiding that feeling of heaviness which so often detracts from study.

The setting out of the subject is also very well done, the reader being taken progressively from an initial explanation of all the methods of bending, through breakdowns of each of these methods, to the final chapter, describing the bending of tubes or pipes " in the field ", a very necessary study for those who may be engaged on a project for which they have very limited equipment. An excellent inclusion is a chapter devoted to the " arithmetics ", enabling the student to calculate lengths and radii of typical bends.

This is a book which should be found, well-thumbed, on the shelves of all methods engineers engaged on pipe work, in technical schools and in the possession of the more fortunate apprentices in the metal working trades. H. J. B.

657.47 COST ACCOUNTING

" Workshop Costs and Costing " by Philip Stephen Houghton. *London, Chapman & Hall,* 1953. 295 *pages. Charts.* £1. 15. 0.

This is a text book on costing by an engineer, written as a result of the author's experience that many firms, even in this modern age, have grossly inadequate costing facilities, but his book contains more detail than is likely to appeal to the directors and managers of such firms.

The emphasis throughout this book is on practice rather than on principle and this, coupled with the fact that the arrangement of chapters is not altogether

logical, may result in those readers who lack previous knowledge of cost accounting having some difficulty in seeing the wood for the trees. Nevertheless, everything the author says is sound, sensible, and clearly stated, so students of any age, or those engineers and managers who are determined to get to the bottom of their costing problems will find the book of real value.

Among the chapter headings are:— Items Met with in a Costing System; Division of the Indirect Expenses; Wage Systems; Creating a Costing System for a New Business; Codes; Foundry Costing; Process Costing; Contract Costing; Stock Accounts; and Reconciliation of Financial and Cost Accounts.

The book ends with nineteen pages of "Questions and Problems". There is an adequate index. C. H. S.

658.58 MAINTENANCE; REPLACEMENT

"Dynamic Equipment Policy . . . a MAPI study" by George Terborgh. *New York, McGraw-Hill,* 1949. 290 *pages.* £2. 7. 0.

The title of this book tends to be a little misleading, since it does not deal with industrial equipment policy as a whole, but is entirely devoted to a very deep study of the problems of equipment replacement. In the concluding summary the author justifies the all-embracing title by putting forward the case that . . . . "if Industry suffers from obsolete and inefficient mechanisation, this is not due primarily to bad policy in the choice of *original* equipment—i.e. the equipment of new or expanded plants; it is due rather to bad policy in the timing of replacements in existing plants. Obsolete mechanisation is first and foremost the result of a degenerative process which develops with the ageing of the industry or the establishment affected" . .

The foregoing quotation represents the theme which runs through every chapter of the book. In the opening chapters the author emphasises that with the heightened tempo of scientific and technical progress, capital goods are increasingly pushed out of service or *dis*placed, rather than merely *re*placed after they expire from physical decay. He stresses the direct influence of depreciation policy on replacement policy, by frequent disinclination to retire assets before the end of their estimated life (especially when their book value is still high). He argues that replacement decisions should be entirely independent of depreciation considerations, and then advances series of arguments on which he bases some standard assumptions which in turn are developed into mathematical formulae to provide a replacement procedure.

The author of this book is the Director of Research of the Machinery and Allied Products Institute, which has its headquarters in Chicago: he was assisted in the preparation of this work by a special Committee of the Institute's members composed of senior executives of companies manufacturing machine tools and similar capital equipment. It should be mentioned here that this Institute has published a number of important studies on subjects in the field of industrial economics, including the widely-publicised "Technological Stagnation in Great Britain", which was based largely on our own Board of Trade Working Party reports prepared immediately following the end of the Second World War.

"Dynamic Equipment Policy" is not easy reading by any means; in fact, it can be said that this is a specialist's book addressed to other specialists. It is stated in the introduction that an abbreviated version of it, for more general reading, is being published. This is to be welcomed because, quite apart from the main theory advanced, there are in it many fundamental observations on replacement policy which are not sufficiently widely appreciated; it would have been a pity if these would have been missed by the general industrial reader who might well be frightened off by the size and academic presentation of the present book. Whilst on the subject of presentation it should be said that the book is well laid-out, with a number of supporting appendices, a glossary and a fine index. The only criticism concerns the constant and voluminous foot-notes which are, to the reviewer, a source of irritation.

It is impossible, within the frame-work of a brief review, to try to explain the theory of replacement procedure put forward in this book. To be of practical value to the individual industrialist, the replacement procedure advanced—simple though it appears itself—will require conditioning calculations which demand some basic knowledge of econometrics. Such being the case, it is of immediate application only to firms who have specialists in this sphere, on their staff or as their consultants. Yet this book should be read by everyone who is interested in the subject and who has the necessary patience to absorb a really fundamental treatise on the subject of replacements. A. G. H.

338.91 RAW MATERIALS; NATURAL ENERGY, etc.

ROYAL INSTITUTE OF INTERNATIONAL AFFAIRS, London. **"World Production of Raw Materials."** *New edition. London & New York, the Institute,* 1953. 104 *pages.* 7s. 6d.

(Information Papers No. 18.)

Published by the Royal Institute of International Affairs, which is an unofficial and non-political body founded in 1920 to encourage and facilitate the scientific study of International questions, this book is a new and revised edition of Information Paper No. 18b, first published in 1941, with the help of Mr. Ronald Brech of "The Economist" and Mrs. A. Vroome and Mr. A. R. Smith, the latter of the Imperial Chemical Industries.

The book is divided into three sections:-

1. Survey of Raw Materials.
2. Notes on sources and uses of the materials.
3. Tables of World production.

1. *Survey of Raw Materials*

Developments in manufacturing capacity have not made possible an equal expansion in the production of raw materials for, in 1950, the production of raw materials was only 10% greater than in the five years immediately prior to the outbreak of War, whilst manufacturing capacity has increased by 40% in the same period.

There are few raw materials won from the ground in a form readily usable in industry and thus raw materials are classified as follows:-

(a) Products of agriculture.
(b) Products of mining and quarrying
(c) Synthetic raw materials.

By geographical distribution the N.A.T.O. countries account for a larger share of the world's raw materials than do the Communist countries.

World production of most raw materials increased rapidly after 1939 and reached a peak during the War years. International Trading Organisations have, since the War, endeavoured to create international co-operation, and mention is made of efforts in connection with United Nations Study Groups to set up an international Commodity clearing house, whilst the International Materials Conference held in January, 1951 attempted to re-constitute a combined Raw Materials Board.

2. *Notes on Sources and Uses of the Materials*

Fibres, agricultural products, metals, non-metallic minerals and synthetic materials are dealt with in detail, with brief notes on the uses of each material and the principal sources of supply both before and since the War.

It is interesting to note that the U.S.A. is the principal producer of many of the materials mentioned, whilst there is little information relative to the U.S.S.R. production, and the use of certain materials.

3. *Tables of World Production*

These show the production of each commodity and the main producing areas in the years immediately before the War and from 1946 to 1951. Where figures of world output are available, percentages are given showing the relative share of each of the main producers in 1950.

Data for U.S.S.R., China and other Communist Countries are incomplete but where possible estimates have been included. The sources given at the end of each table indicate the main publications from which the figures have been compiled and these include the American Bureau of Metal Statistics, British Bureau of Non-Ferrous Metals Statistics, as well as Commonwealth Economic Committee and the various study groups previously referred to.

There is a wealth of information in the book. Whilst the Institute as such is precluded by the terms of its Royal Charter from expressing an opinion on any aspect of international affairs, any opinions expressed therefore, are stated to be not those of the Institute.

R. N. M.

669.14 STEEL

" Engineering Steels : A Study of the Properties of Steels and the Principles Governing their Selection for Engineering Applications," by Leslie Aitchison and William I. Pumphrey. *London, Macdonald & Evans,* 1953. 923 *pages. Illustrations. Diagrams.* £5. 5. 0.

I have said before that books on materials date easily. I must now qualify that statement and say that the " usual " types of materials text-books date easily.

In Aitcheson and Pumphrey's " Engineering Steel ", we have an exceptionally fine book written by two renowned authors at their best.

The book is intended for the practical engineer rather than the trained metallurgist, but when it is appreciated that there are 923 pages packed with information I am inclined to think that the practical engineer will become a metallurgist when he has assimilated their work.

The subject of steels is covered from the making of ingots at the beginning to scrap recovery at the end—thus completing the cycle. There are chapters on carbon steels, alloy steels, stainless, tool, creep-resisting, heat resisting and cold-worked steels. Mechanical testing is adequately covered. Brazing and welding, machinability, corrosion and protection are all dealt with very thoroughly. One very small criticism is that Chapter 4 is entitled " Hardenability ", Chapter 11 is called " Surface Hardening ", whilst Chapter 17 is " Hardenability and its application ". I should have thought that these three chapters could follow each other, say as three sections of the same chapter.

The presentation of the subject matter is carried out in a very lucid manner. The chapters are divided into sections each with its own heading. The important facts or operative phrases are in heavy type, consequently making it very easy for reference.

There are many tables of steel properties, which, although perhaps not unique are very uncommon and are of great use to designers and the like. As an example, Table 150 on page 842, giving values of " E " for different temperatures from 20°C. up to 100°C., can be usefully employed in valve spring design.

I consider that this work may be termed a classic. The subject is dealt with completely without limitation for any examination syllabus. Although the language is very clear and easily understandable, the book is certainly not written " down " to a certain level. I would recommend this volume to anybody requiring information on steels. The student can pick out relevant information with the minimum of trouble. Similarly the advanced research worker may quickly select his references. The designers and technicians can not only obtain their figures from the table, but with very little reading can readily understand how the figures were obtained.

R. E. M.

371.126 TRAINING OF TEACHERS

" Techniques of Technical Training " by H. R. Mills. *London, Cleaver-Hume Press Ltd.,* 1953. 195 *pages.* 10s. 6d.

The attitude in industry towards technical training and education has changed considerably in the last fifteen years. The progress made in this direction is one of the good things that comes out of modern war, for the stimulus of war production has undoubtedly been a major factor in making industry realise the value of investment in education.

The number of people who are directly concerned with some form of training or education has increased enormously during this period and many of them, perhaps the majority, will have had no training themselves in the techniques of instructing others. Mr. Mills' book will be of great value and interest to these instructors and, although it is written for the instructor in industry, much of it will apply to part-time and full-time teaching in technical institutions.

In his opening paragraph in the first chapter, " The Background to Training ", the Author says " The training of a young man or apprentice in industry begins from the moment he arrives at the gates of the works ". He goes on to discuss the preparation and presentation of instruction with particular emphasis on the methods and artifices used to ensure that the maximum benefit is obtained by the class. He emphasises the importance of maintaining class interest by breaking up periods of instruction with question and answer or other forms of class participation.

Chapters are devoted to examination and testing techniques for both theoretical and practical work, the analysis of pace of instruction and difficulties in learning, and to various methods of instruction. The use of training aids such as wall charts, projectors and models is described and a separate chapter deals with the use of films.

The value of most technical books is greatly increased if a bibliography is included; this book contains over fifty references in its bibliography, ranging from the organisation and administration of technical colleges to the pedagogical implications of wiping a joint.

The Author's style is clear and straightforward; the book is adequately illustrated with line diagrams, graphs and charts, and can be recommended to all who are interested in any aspect of technical training.

K. J. H.

621.793 METAL COATING

" Metallizing Handbook " by H. S. Ingham and A. P. Shepard. *5th edition. New York, Metallizing Engineering Co. Inc.; Chobham, Metallizing Equipment Co.,* 1951. 249 *pages. Illustrations. Diagrams.* £2. 2. 0.

A very detailed and instructive publication for both the practical engineer and student, and is specially recommended to maintenance, erection and production engineers.

The basic principle of metallizing is a process in which molten metal is sprayed on to a prepared surface to form a coating, and the book commences with a brief resume of the historical development and basic principles involved in the process.

The most common application of the process is in machine element work for building up worn or faultily machined parts and the second chapter deals extensively with the methods of surface preparation, spraying technique and finishing methods. In this field there is undoubted economic advantages for its use.

Another application of the process is for corrosion resistant purposes. Obviously the complete subject of corrosion is not covered by the book but a brief discussion of metal galvanic corrosion leads the reader to further thought about the advantages and limitations of the processes for corrosion resistance applications. A chapter dealing with this more specialised application discusses coating selection, surface

preparation and the techniques involved in spraying, sealing and finishing. It is claimed that for some applications the economics of the process can compete favourably with plating and painting and gives better protection.

The specialised applications, such as the metallizing of glass and ceramics and many other normal non-metallic materials, the repairing of casting blow holes, brazing and the application to the sealing of electrical circuits, are covered by a further chapter.

A special alloy giving hardness values of from Rockwell C.56 to 61 for hard facing applications is also discussed and the book finishes with chapters on the technical and engineering data of a wide variety of sprayed metal, safety measures and ventilation recommended for the various processes involved. H. G. P.

531.7 METROLOGY

" Practical Metrology, Volume I " by K. J. Hume and G. H. Sharp. *London, Macdonald & Co. Ltd.,* 1953. 60 *pages. Diagrams.* 6s.

This book is the first of four small volumes designed primarily to aid the student of metrology in his practical laboratory work. A brief survey is made of basic equipment followed by a chapter devoted to fundamental methods. Twelve experiments are described including the measurement of parallel and taper plugs and rings, gap gauges, height of spigots, flush pin depth gauge, and plug screw gauges. Methods are also described for checking engineer's squares and straightedges, also the calibration of micrometers.

When a book comes from the pens of practical experts like Hume and Sharp, one expects the result to attain a very high standard. The reader will not be disappointed. The writers clearly describe twelve tests which might be termed the bread-and-butter jobs of a metrology department or college metrology course.

The book, together with the three volumes yet to be published, should be of the greatest value to metrology instructors. The price is sufficiently low to enable them to be bought by students and the books could well replace many of the " lab. sheets " which have been prepared for students use.

The book may be summarised by an extract from Mr. Loxham's foreword: " Technical College lecturers and instructors, inspectors, craftsmen, apprentices, and many others, will obtain great benefits from studying this book, because it indicates, probably for the first time, and in a very convenient form, a technically correct method of carrying out a group of typical experiments in Engineering Metrology ". S. R. S.

621.791 WELDING

It is regretted that in the review of the British Welding Research Association's publication, " Welding of Austenitic Corrosion and Heat-Resisting Steels ", last month, the price was incorrectly given as £1. 17s. 6d. The actual price of this publication is £1. 7s. 6d.

OTHER ADDITIONS

338.96 EXTENT OF BUSINESS

Florence, P. Sargant, *and* Baldamus, W. **" Investment, Location, and Size of Plant: A Realistic Inquiry into the Structure of British and American Industries."** *Cambridge, University Press,* 1948. 211 *pages.* (National Institute of Economic and Social Research—Economic and Social Studies, No. 7.)

340 LAW

Great Britain—Laws, Statutes, etc. **" Iron and Steel Foundries Regulations, 1953."** *London, H.M.S.O.,* 1953. 6 *pages.* 4d. (Statutory Instruments. 1953, No. 1464.)

378.996 EDUCATION

British Engineers' Association (Inc.), London, *and* British Electrical and Allied Manufacturers' Association (Inc.), London. **" Management Training."** *London, the Associations,* 1952. 16 *pages.*

519.2 STATISTICS ; THEORY OF PROBABILITY

Moroney, M. J. **" Facts from Figures."** 2*nd and revised edition. London, Penguin Books,* 1953. 472 *pages. Diagrams.* 3/6d. (Pelican books.)

Mueller, Robert Kirk. **" Effective Management through Probability Controls : How to Calculate Managerial Risks."** *New York, Funk & Wagnalls Co., in association with Modern Industry Magazine,* 1950. 310 *pages. Illustrated. Charts.* (Modern Industry Books.)

607 RESEARCH

Federation of British Industries, London—**" Conference of Industrial Research Directors and Managers, No. 3, 1953."** Report of the . . . Conference . . . the commercial utilisation of research results. *London, the Federation,* 1953. 70 *pages.* 3/6d.

Great Britain—Mechanical Engineering Research Board. **" Mechanical Engineering Research, 1952."** *London, H.M.S.O.,* 1953. 60 *pages. Illustrated. Diagrams.* 2/6d.

620.1 STRENGTH OF MATERIALS

Judge, Arthur W. **" Engineering Materials."** 2*nd edition. London, Pitman,* 1943-5. 2 *volumes. Illustrated. Diagrams.*

621.77 MANUFACTURE OF SHEET, PLATE, TUBE, etc.

Gregory, Edwin, *and* Simons, Eric N. **" Mechanical Working of Steel."** *London, Pitman,* 1943. 198 *pages. Illustrated. Diagrams.*

621.795 SURFACE PROCESSES ; FINISHING

Dow Chemical Company, Midland, Michigan. **" Magnesium Finishing."** *Midland, the Company,* 1952. *Pages* 128 + xii. *Illustrated. Diagrams.*

Nelson, J. H. *and* Silman, H. **" Application of Radiant Heat to Metal Finishing : A Critical Survey of the " Infra-red " Process for the Stoving of Paints and Enamels."** 2*nd edition. Revised. London, Chapman & Hall,* 1945. 91 *pages. Illustrated. Diagrams.*

621.888 SPRINGS

Hodgson, Alan. **" Leaf Spring Design."** *West Bromwich, Richard Berry & Son,* 1953. 60 *pages. Diagrams.*

621.794 SURFACE TREATMENT OF METALS

Imperial Chemical Industries Ltd., London. **" Phosphating—in Principle and Practice."** Report of a Conference . . . at . . . Birmingham . . . 1953. *London, The Firm,* 1953. 69 *pages. Illustrated.*

621.822 BEARINGS

Willi, Albert B. **" Handbook of Sleeve Bearings."** *Detroit, Federal—Mogul Corp.,* 1941. 250 *pages. Illustrated. Diagrams.*

621.83 GEARS

Cincinnati Milling Machine Company, Cincinnati, Ohio. **" Cutting Gear Teeth on a Milling Machine."** *Cincinnati, The Company,* 1952. 59 *pages. Illustrated. Diagrams.*

621.884 RIVETS ; RIVETING PROCESSES

Francis, A. J. **" Behaviour of Aluminium Alloy Riveted Joints."** *London, Aluminium Development Association,* 1953. 95 *pages. Illustrated. Graphs.* 7/6 (A.D.A. Research Report No. 15.)

621.918 FILES ; FILING MACHINES

Diprofil Technique. Stockholm. **" Diamant-Produkter AB, 1952."** 60 *pages. Illustrated. Diagrams.*

621.919 REAMING ; BROACHING

National Broach & Machine Company, Detroit. **" Broaching Practice."** *Detroit, The Company,* 1953. 80 *pages. Illustrated.*

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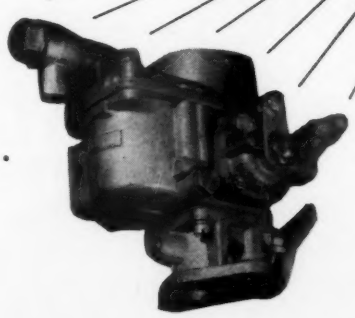

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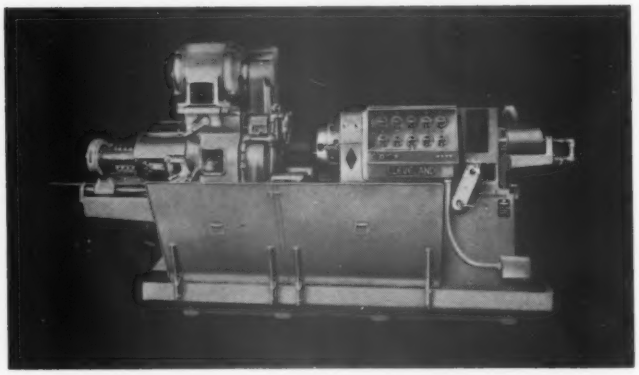

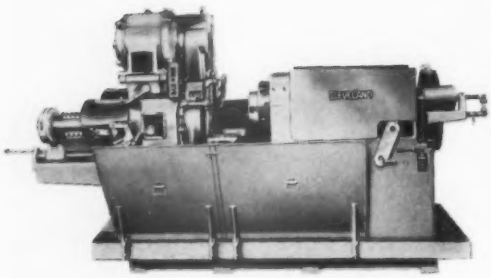

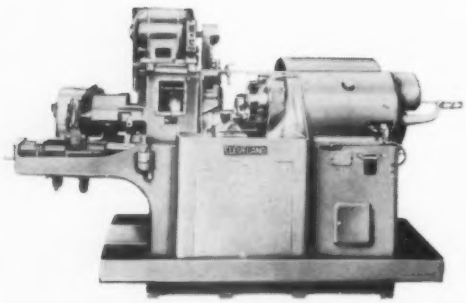

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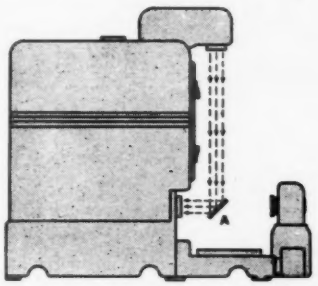
5312 SMT 140

Plain Pointers on Projection

AMONG the definitions listed by Webster for the adjective *universal* is: " adapted or adaptable to all or to various uses, sizes, shapes, et cetera " —a definition we like to feel applies to Kodak Contour Projectors.

Admittedly, we make two projectors, one for routine inspection gauging (the low cost of which might surprise you) and a second for tool-room use affording measurements to " tenths ". Optically, however, these two instruments are one. And it's their optical system which makes them truly " universal ".

Back in the early days of design, our engineers set out to provide in a single contour projector light sources both for horizontal and for vertical shadow projection. They also developed the unique Kodak Surface Illuminator, a self-contained light source which affords surface projection in either plane. Their reasoning was economic. By combining these features, the instrument could be easily adapted to a wide range of parts; the more uses to which the projector might be put, the sooner it would pay for itself in the shop.

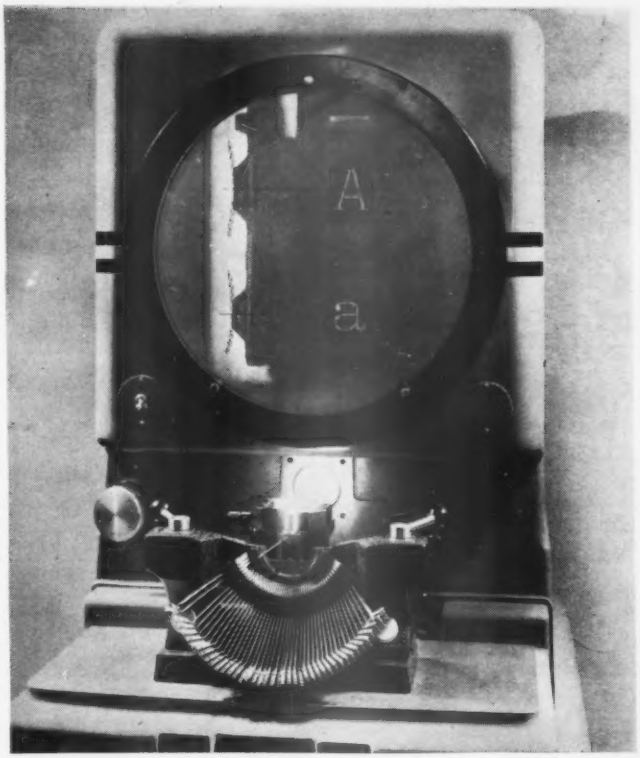


Above drawing illustrates how vertical light source is utilized. With part on a glass staging platform, image is reflected by mirror (A) into optical system of projector.

Nothing has happened since the design stage to shake us in this belief. However, we have been somewhat surprised by some of the highly ingenious ways in which our projectors are used: as in the case of the typewriter fixture (illustrated in our advertisement at the right), where the surface illuminator yields a simultaneous plan and profile view of the type bar face.

Equally ingenious, if not more so, is a device which employs both the horizontal and vertical light beams to simultaneously project the shadow image of a shaft and a reticle scale for gauging its tolerances. A description of this application, which runs to more words than space here affords, is available on request from Gaston E. Marbaix Ltd., Devonshire House, Vicarage Crescent, Battersea, London, S.W.11. Just ask for the folder on the new, universal shaft checking fixture.

Applications such as these have opened the eyes of many engineers to the fact that inspection by optics today has overcome traditional limitations. In the best sense of Webster, contour projection may be " adapted to various uses, sizes, shapes, et cetera ". And to the solution of various problems in inspection and precision measurement, including, perhaps, your own.



This "3-D picture" showed the way to cut aligning time 25%

What you see here on the Kodak Contour Projector is both the *front* and *side* view of a typewriter type bar—a picture that helped reduce aligning time 25 per cent. at Commercial Controls Corp., manufacturers of tape-controlled Flexowriters and Justowriters. Light reflected from the surface of the type character provides an image for rapidly checking horizontal and vertical alignment of the letter. Simultaneously mirrors in the special holding fixture project a profile image of the type—yield an accurate check of the desired position of the letter as it will contact the platen. Only the Kodak Contour Projector's unique surface illuminator makes possible this combined plan and profile view. Alignment of type is a critical factor on these automatic machines which type at 100 words a minute and must produce copy for printing reproduction. Until recently, Commercial Controls had to perform this inspection operation during final assembly. Now, this new gauging technique has made it possible to inspect the type bars immediately after their removal from the soldering jigs. Each bar is quickly moved into place and compared with the tolerance lines of the chart-gauge on the screen. Alignment of letters is held to a tolerance of ± .0002 inch, contact to ± .0015 inch. And, by catching errors at this point, aligning time has been cut 25 per cent. Perhaps the speed, precision, and economy of optical gauging can help you solve a difficult inspection or measurement problem. Our representative will be glad to call and discuss your problem with you. You can get in touch with him or obtain a copy of the booklet, " The Kodak Contour Projector ", by writing to:

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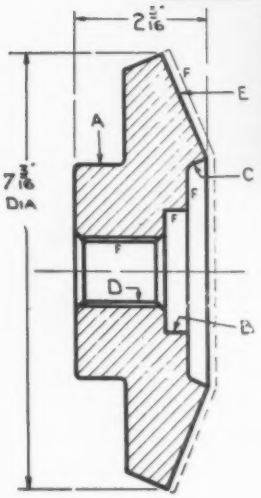

DESCRIPTION OF OPERATION	Tool Position		Spindle Speed R.P.M.	Surface Speed Ft. per Min.	Feed Cuts per inch
	Hex. Turret	Cross-slide			
Chuck on A	—	—	—	—	—
Rough Face End	—	S.T.1	240	260	93
Rough Bore B	1	—	500	260	Hand
Recess Bore C	2	—	240/35	240/35	Hand
Chamfer Bores	3	—	700	690	Hand
Finish Bore B and Bore D	4	—	1000	525	270
Rough Angle Face E	—	S.T.2	240	450	133/Hand
Finish Angle Face E (2 cuts)	5	Rear	240/350	450/650	93/133
Tap 1 1/8" × 14 T.P.I	6	—	70	20	14
Chamfer O/dia	—	S.T.2	70	130	Hand
Remove	—	—	—	—	—

50 Ton Tensile Steel Forging. En.9 Tungsten Carbide Cutting Tools

Floor to Floor Time · 10½ minutes

The Ward No. 7 'Prelector' Combination Turret Lathe has been designed for production from bars up to 2.1/2 in. dia. and chuck work having a maximum swing of 16in. over the bed covers. Special features incorporated in the machine include the patented hydraulic preselecting speed change system which provides for setting the speed for any operation whilst the previous operation is running. Maximum production within the capacity of the lathe is ensured by making full use of Tungsten Carbide cutting tools. The Bevel Wheel Blank illustrated above is a typical example of work produced on the No. 7 'Prelector' Combination Turret Lathe.

OUR EXTENSIVE RANGE INCLUDES CAPSTAN AND TURRET LATHES WITH CAPACITIES UP TO 35 in. SWING OVER THE BED.

Full details on application.

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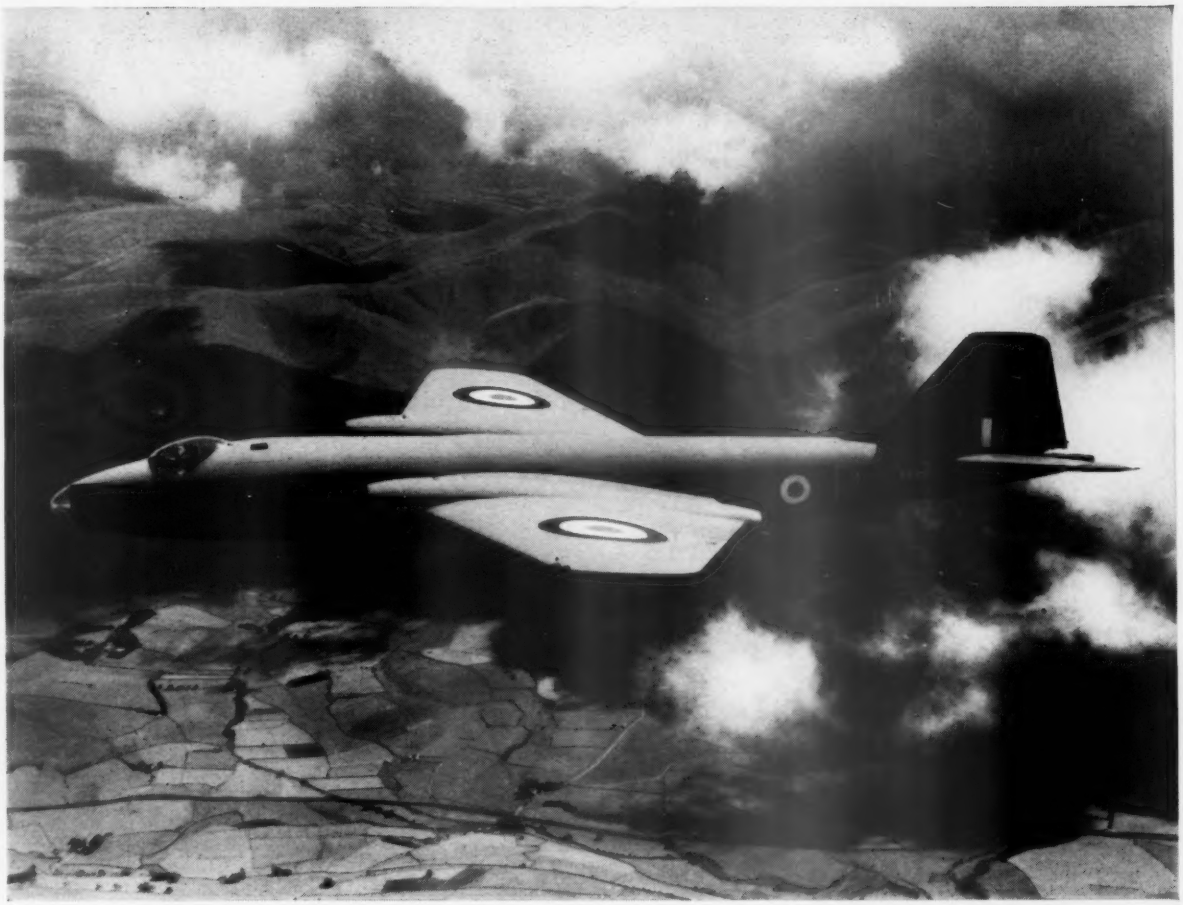
SELLY OAK TELEPHONE **BIRMINGHAM 29** SELLY OAK 1131

W.598.A

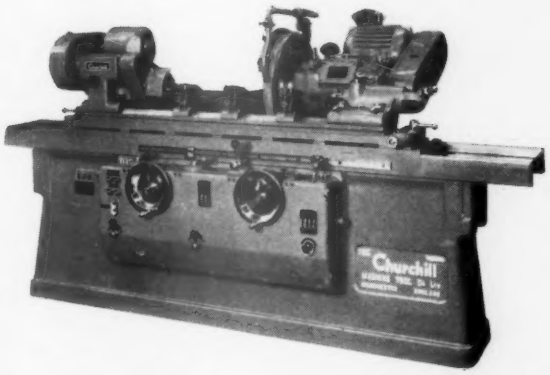


'English Electric' Canberra
(Photograph by permission)

Churchill

By their ability to maintain low limits and fast production rates CHURCHILL Precision Grinders make an important contribution to the outstanding achievements of the British Aircraft Industry.

Illustrated here is the CHURCHILL Model 'BW' 10" x 36" Plain Grinding Machine; can be supplied as a non-automatic or a fully automatic Plain Grinder.



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Export Sales Organisation: Associated British Machine Tool Makers Ltd. London, Branches and Agents.

Home Selling Agents: Charles Churchill & Co. Ltd., Birmingham and Branches.

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This close up of the MAXICUT No. 2A Gear Shaper shows gear blanks being 'clocked' with ease by turning the work-spindle from the side of the machine.

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Change gears are conveniently located at the side of the machine—another MAXICUT time-saving feature.

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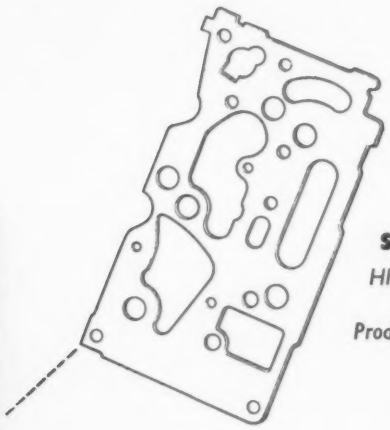
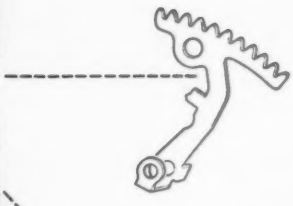
. . step up production of small components

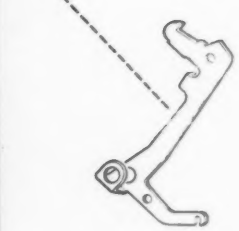
FOR BURROUGHS ADDING MACHINES



SIDE FRAME
HI-TON Operation
Straightening
Production 300 per hr.



SECTOR
HI-TON Operation
Broaching,
Paralleling,
Squaring,
Hole size : ·127" ± ·0005"
Production 640 per hr.



CARRY LATCH
HI-TON Operation
Sizing
Production 600 per hr.

There are HI-TON presses in capacities from 1 to 250 tons

By installing these presses BURROUGHS ADDING MACHINE LTD. are obtaining the most consistent standard of production with rapid operation at low cost. As HI-TON self-contained hydraulic presses are under sensitive hand or foot control a high hourly output can be maintained throughout the day without operator fatigue. *Why not send us YOUR pressing or assembly problems—?*

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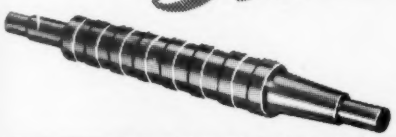
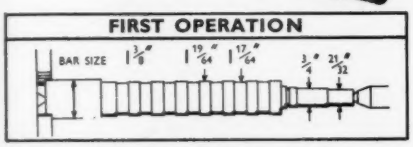
Rapid Copying Lathes

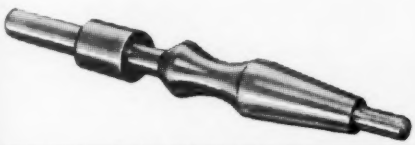
Slash production times...

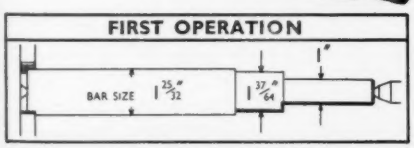




Material St 60. 11
First operation 138 secs.
Second operation 67 secs.
Total time
3 minutes 25 seconds

These lathes copy direct from a workpiece or from a 1:1 templet. Hydraulic power is applied to the feed and rapid return of the longitudinal slide. Parts with shoulders of 90°, tapers, concave or convex forms, etc., are produced in very fast times to a high degree of accuracy and with fine finish. Height of centres $4\frac{11}{16}$". Available with distance between centres $15\frac{3}{4}$" or $25\frac{5}{8}$".





Material St 50. 11
First operation 137 secs.
Second operation 251 secs.
Total time
6 minutes 28 seconds

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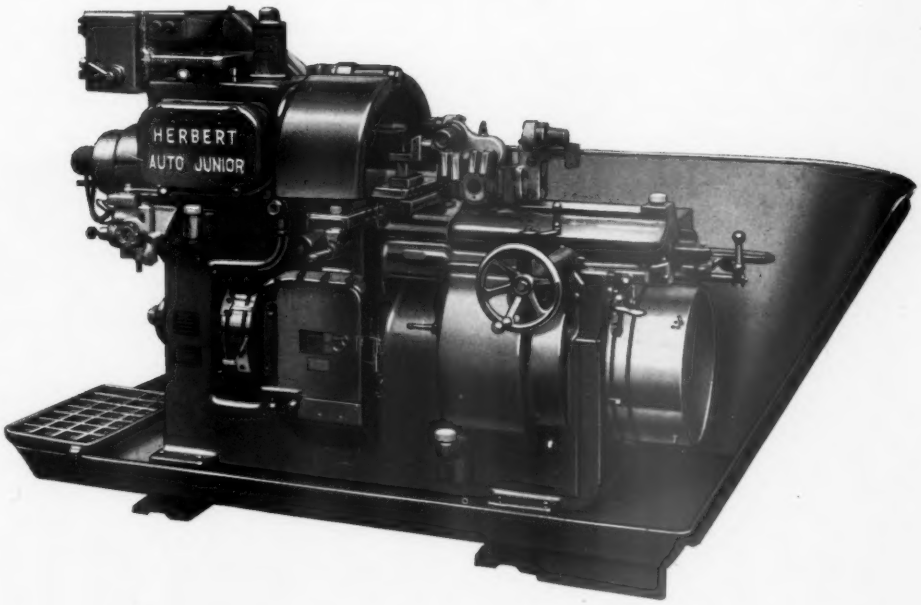

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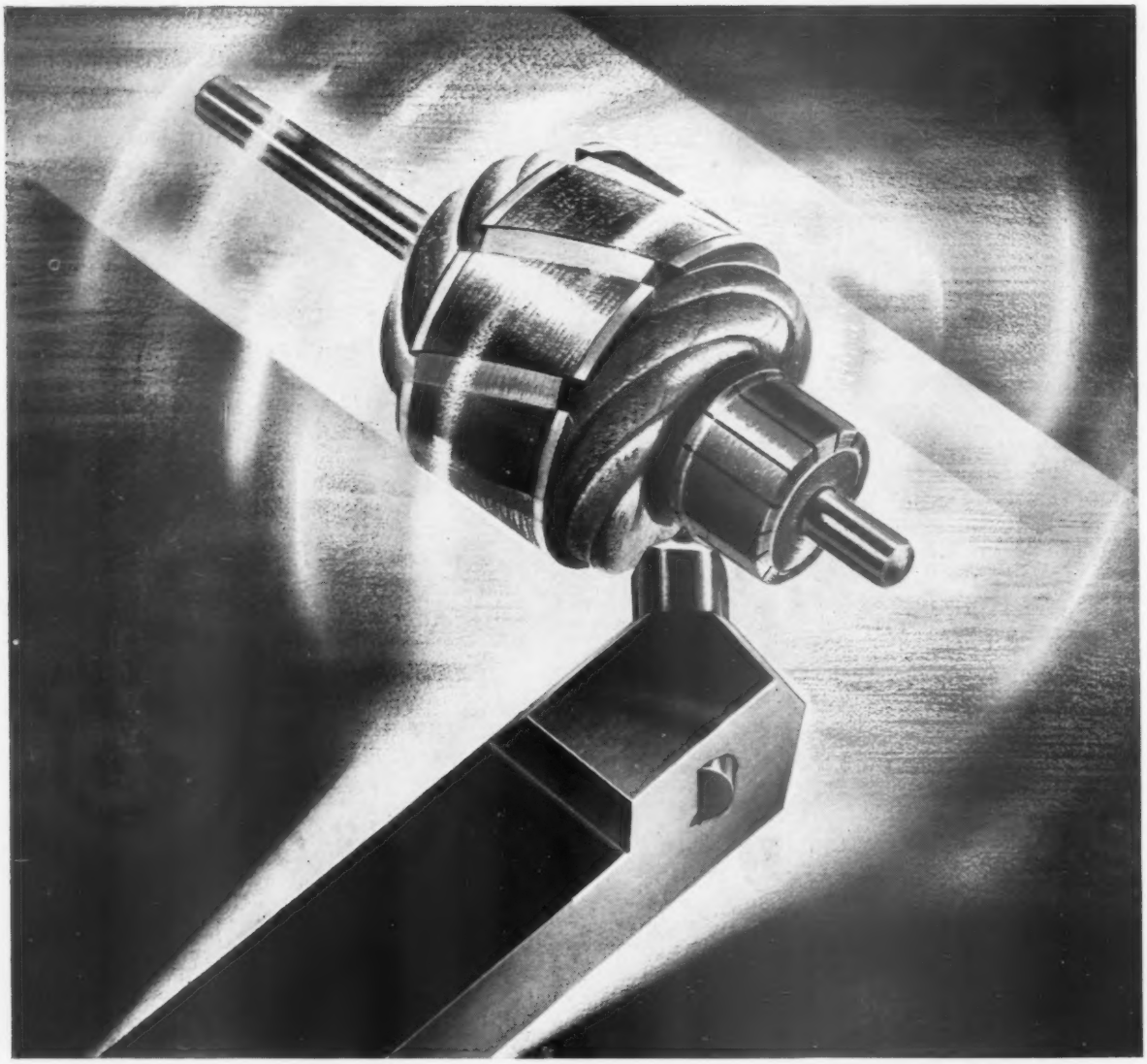
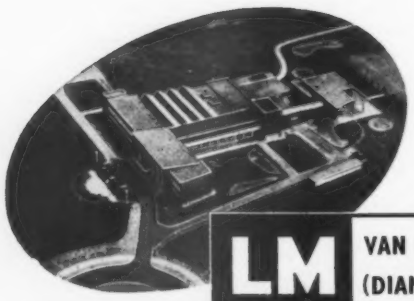


the domestic diamond



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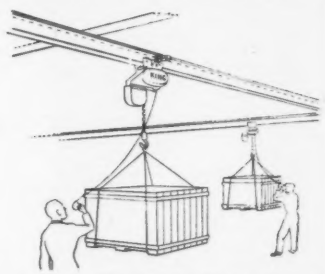
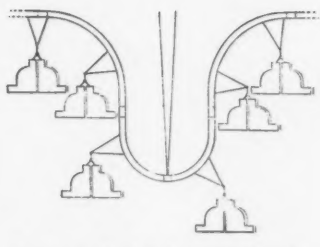


A KING *Marvex Electric Pulley Block and runway*



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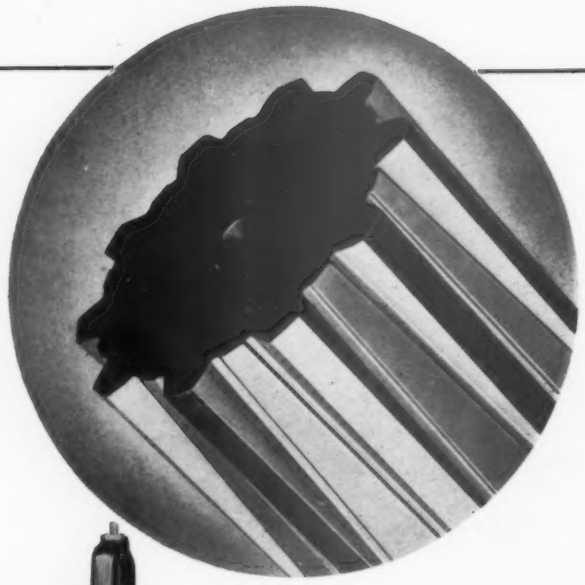

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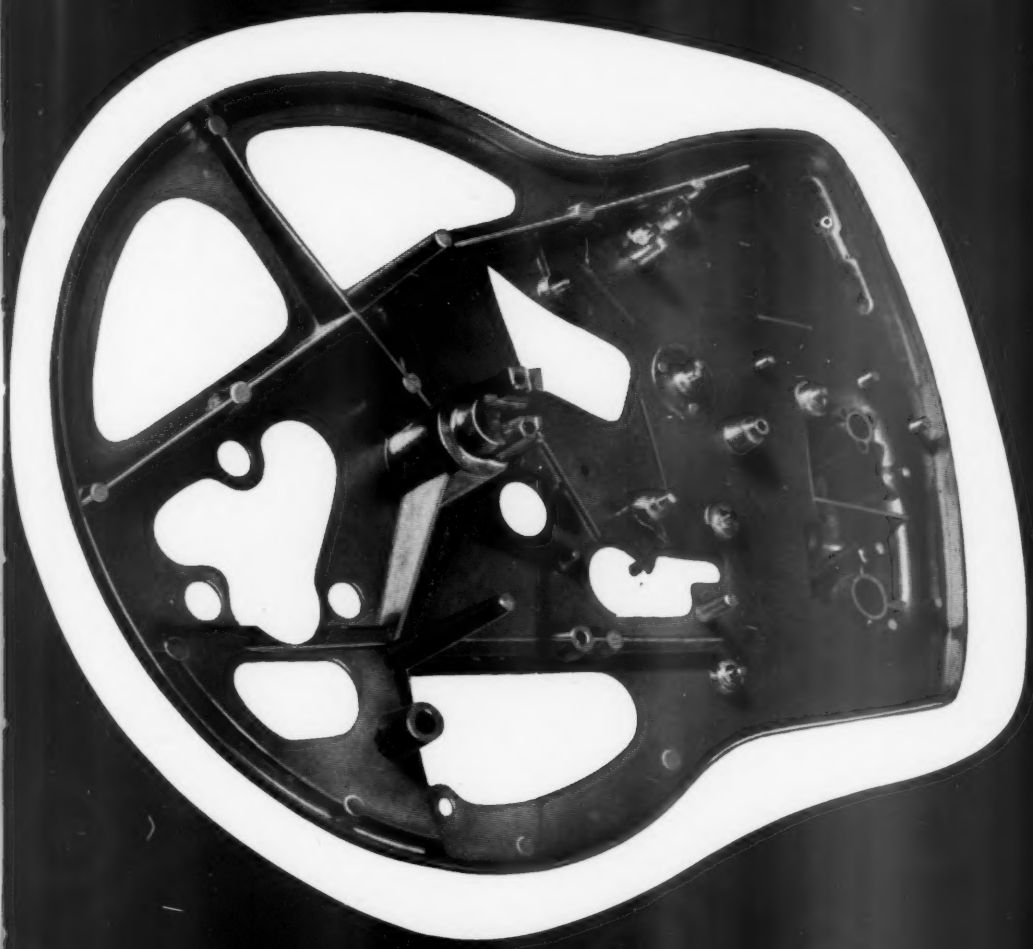
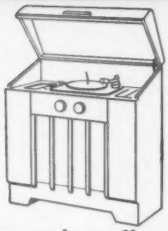
THINK ZINC





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Maximum length of plunge ground work ...3½″
Grinding wheel :
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Speed ... 2,000 rpm
Motor ... ... 3 HP

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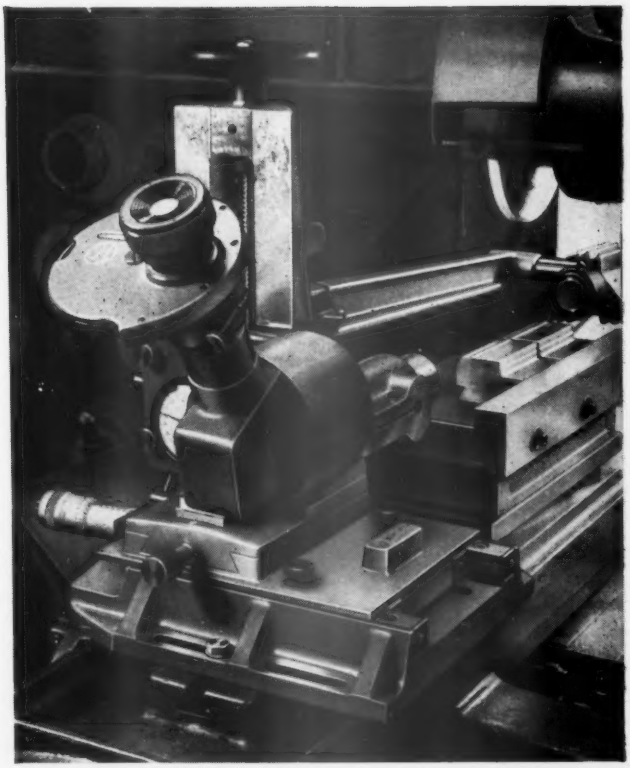

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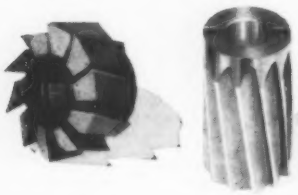

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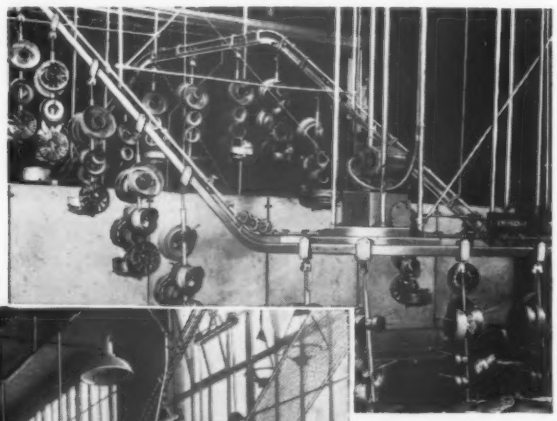
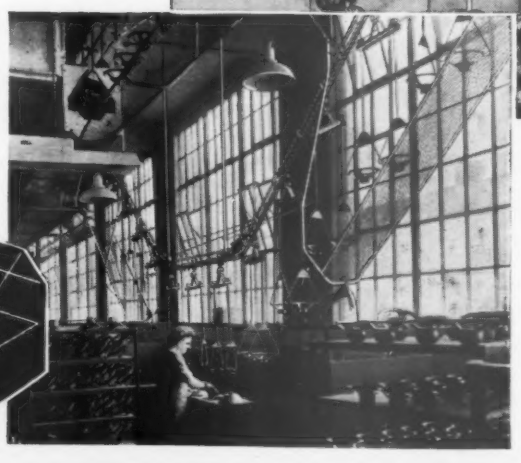
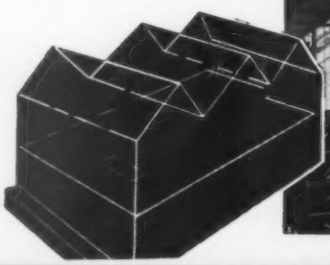
It is almost certain that some stage of production or packing of your product can be economised and speeded up by the installation of one or other of the Teleflex Conveyor Systems. Either Cable or Chain type conveyors can be supplied soon after receipt of your order. Our Technical representative will be pleased to call upon you (entirely without obligation), and advise on the solution to your problem. Write for illustrated brochures:—Cable Conveyors ref: Con. 1 I. P. and Chain Conveyors ref: Con. 2 I. P.





Above:
Teleflex conveyors form an important aspect of the production system of Messrs. A. C. Delco—Division of General Motors

Left:
Teleflex conveyors are important links in the production lines at the works of the Plessey Co. Ltd., Ilford.



Illustrated is an example of a Teleflex Conveyor which travels all round a particular factory.

Telephone: ILFORD 3117

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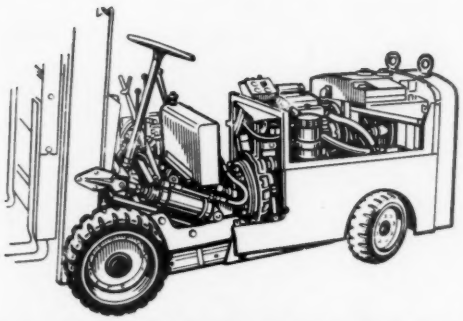
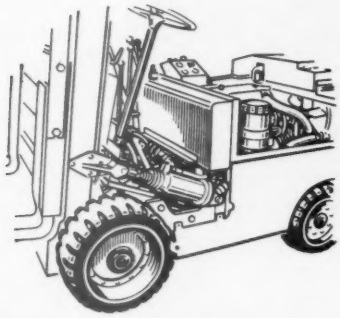
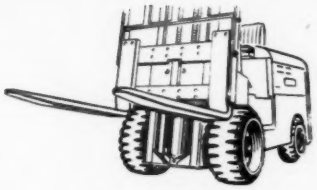
STACATRUC – a capital investment





AN "OPEN-AND-SHUT" CASE FOR USING THE NEW 3-TONNER



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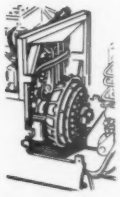
HYDRAULIC PACK



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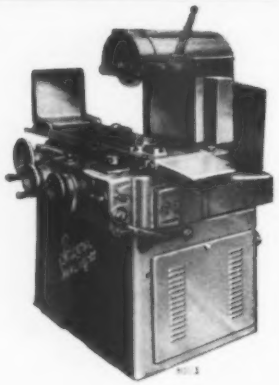

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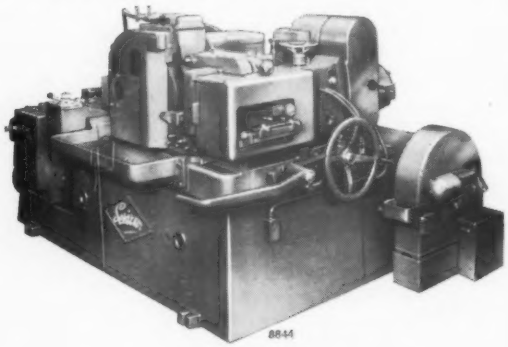

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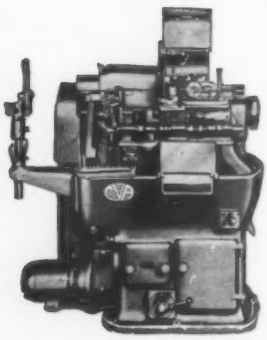

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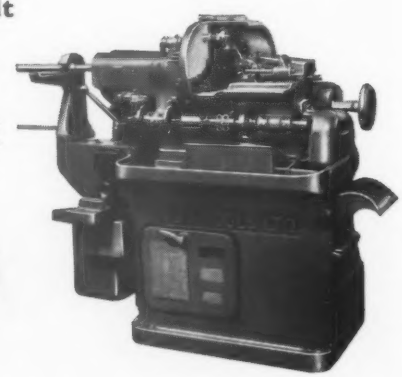

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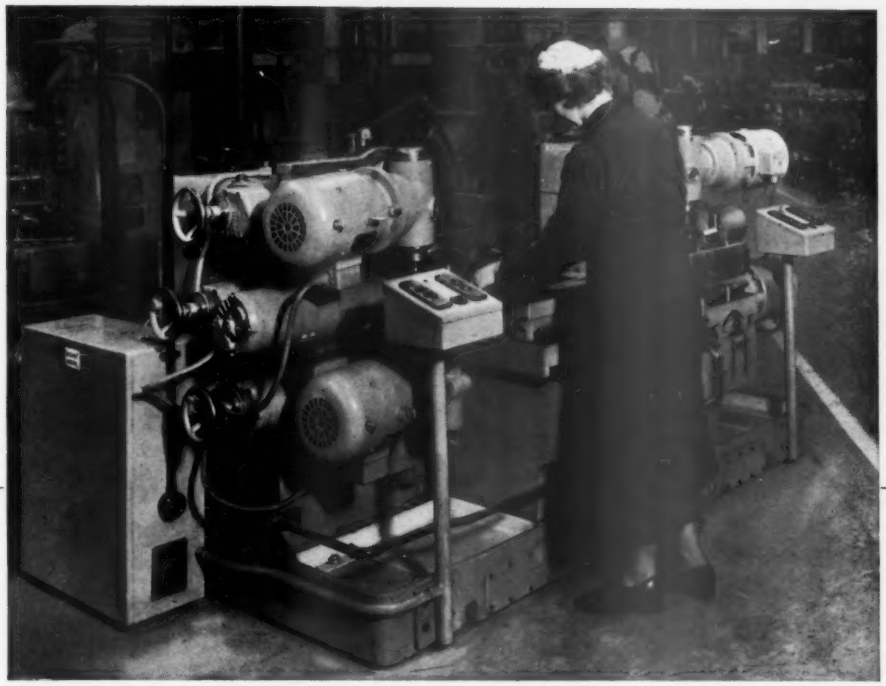
Fractional horsepower motor applications



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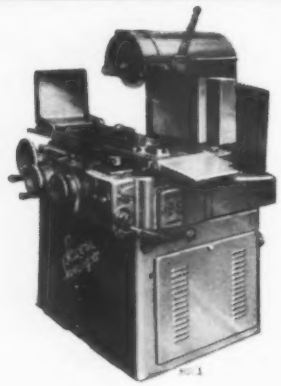

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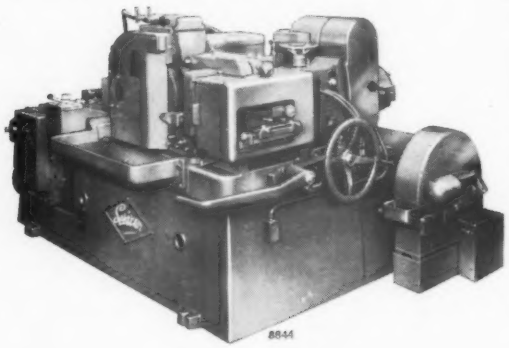

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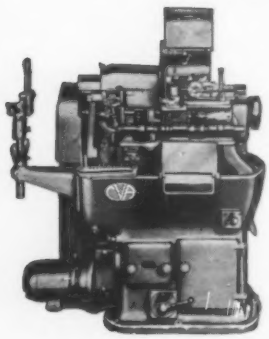

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Fractional horsepower motor applications

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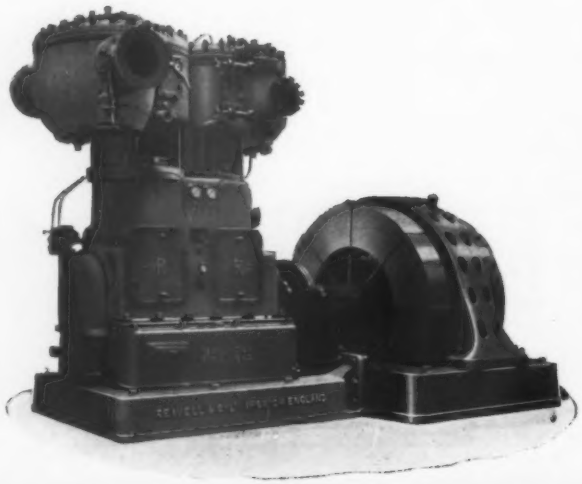

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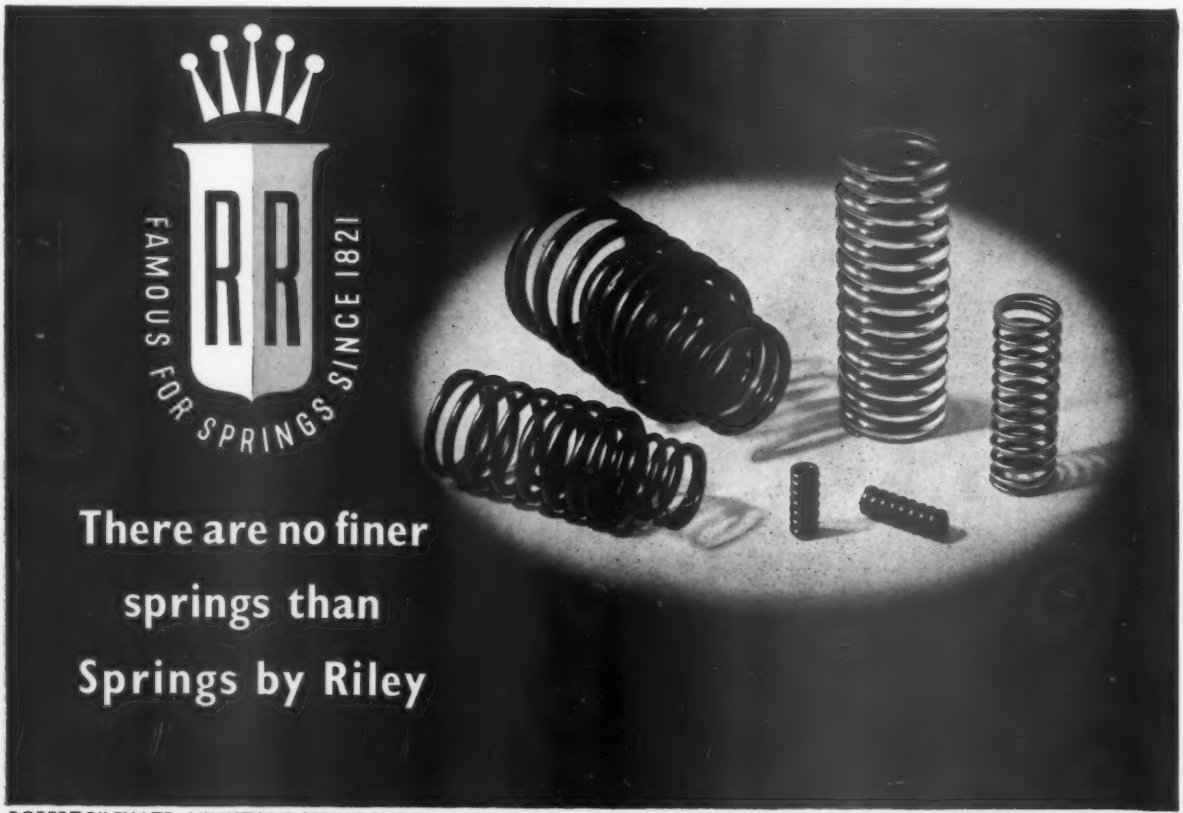

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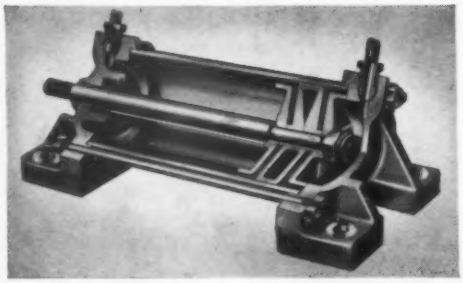

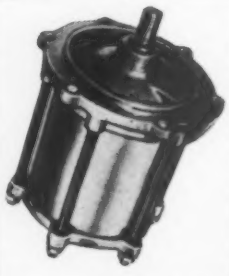

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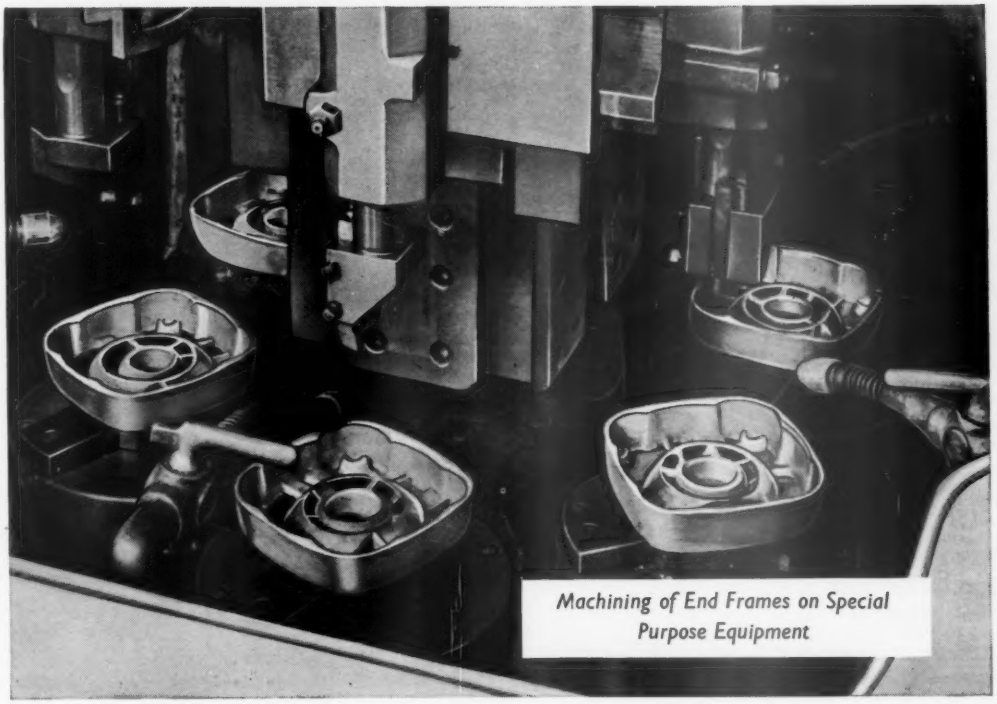

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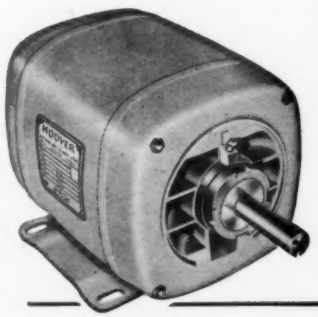

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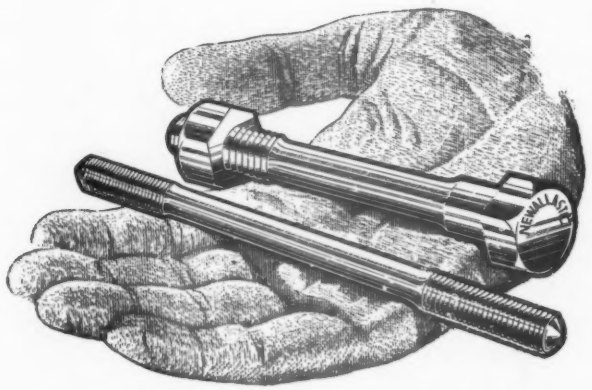

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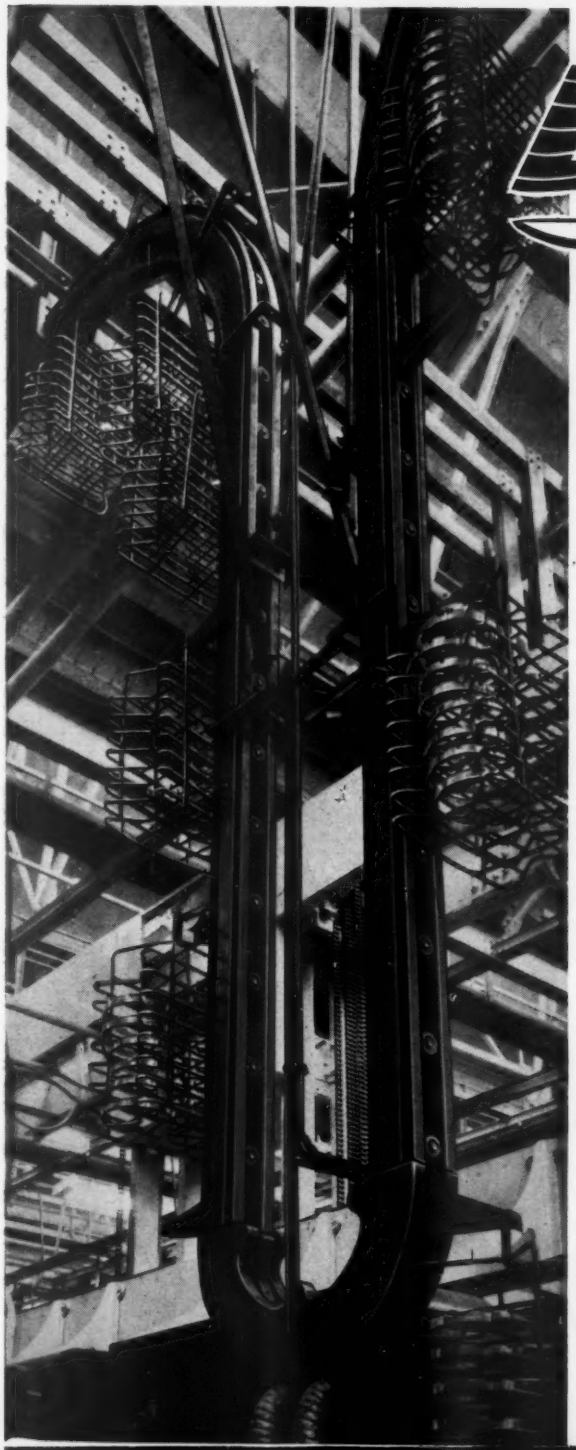

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A PECO 5c DIE CASTER

'ironed out' the production problems

of this sole plate

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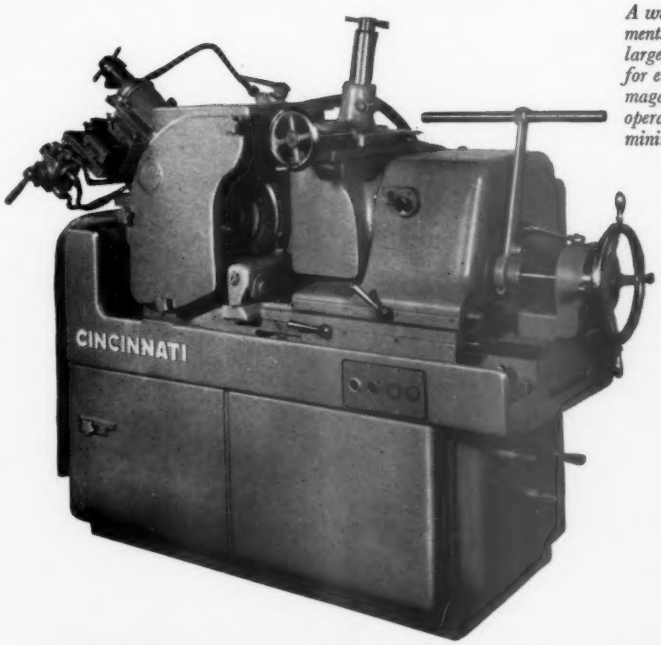

A wide range of attachments aids production of large or small quantities; for example, hopper and magazine feeds reduce the operator's duties to a minimum.

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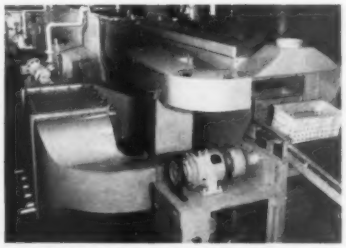
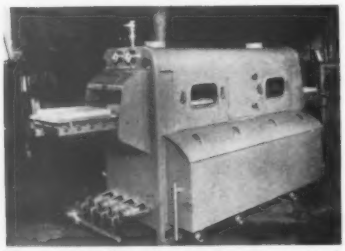
can be designed to meet your particular cleaning problems

This illustration shows a machine cleaning crank cases in the production line. It is equally capable of cleaning small parts in baskets.



A power driven conveyor system is employed with this cleaning machine for ball bearings.



Trays carrying the work are pushed through on a roller conveyor by hand in this cleaning installation.

Whilst offering a very wide variety of standard cleaning equipment, it is BRATBY policy, wherever possible to design the machine to meet the particular cleaning problem. Careful study of each individual problem ensures maximum efficiency and economy of the plant in operation. The illustrations show but a few of the specific types of Cleaning Machines designed by BRATBY for individual needs.

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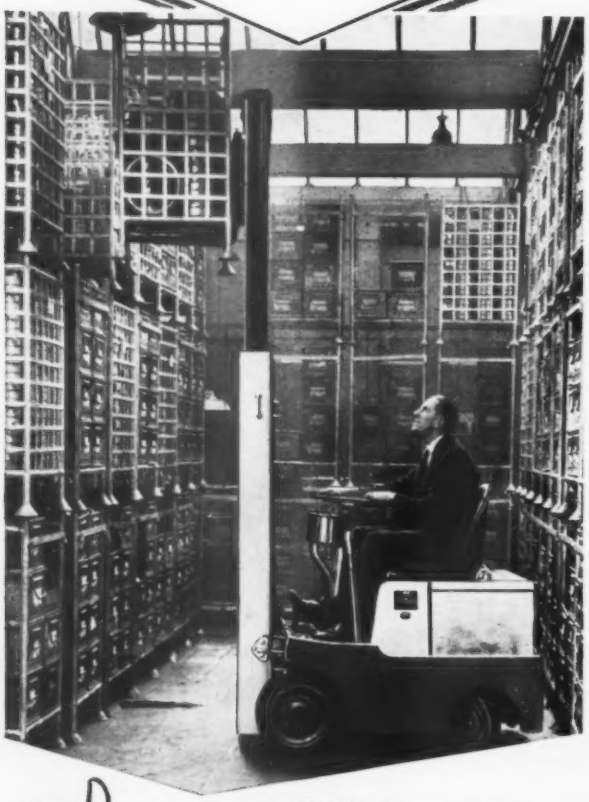

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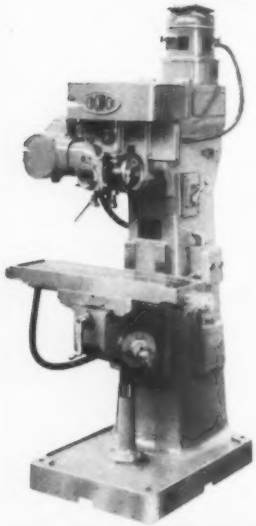

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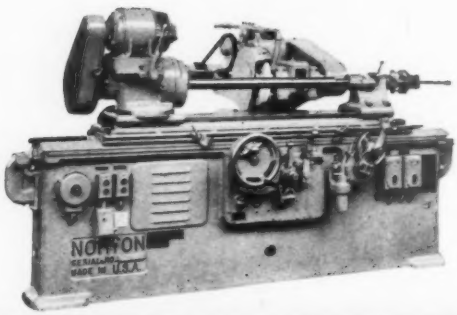

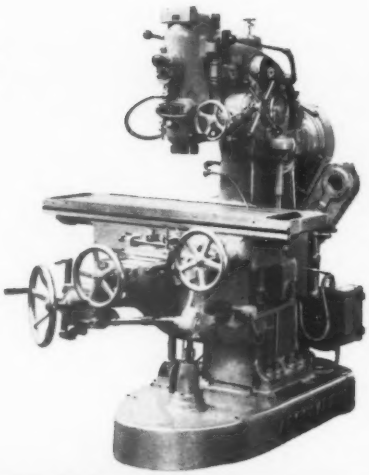

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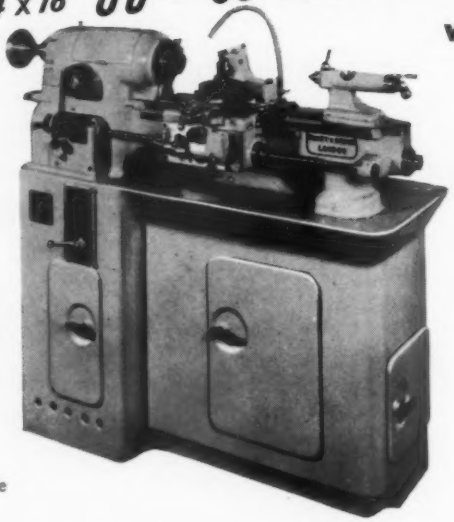

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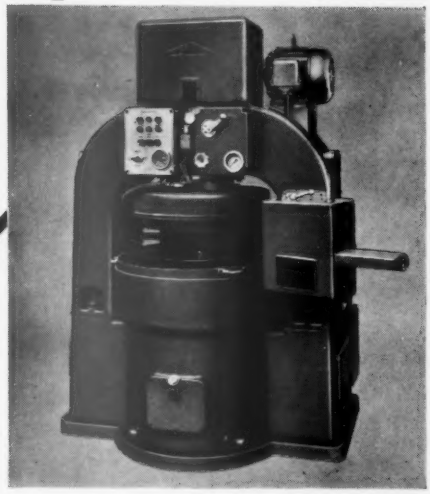

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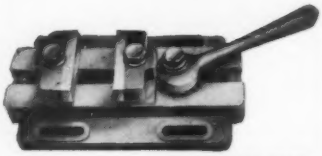

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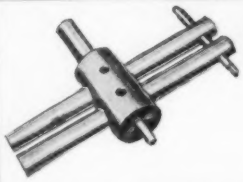

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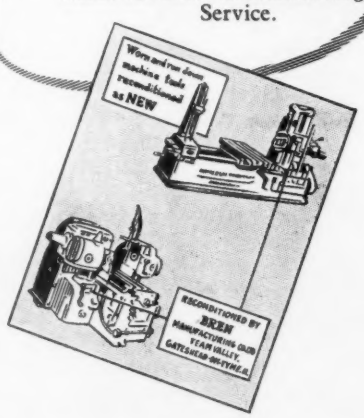

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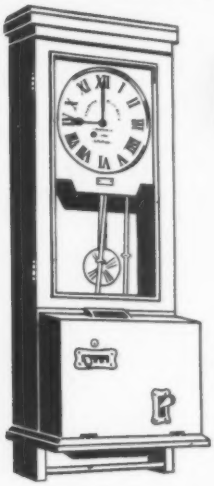

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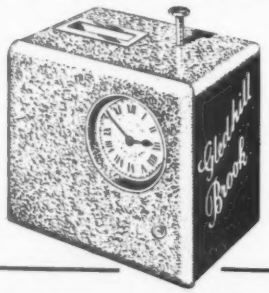

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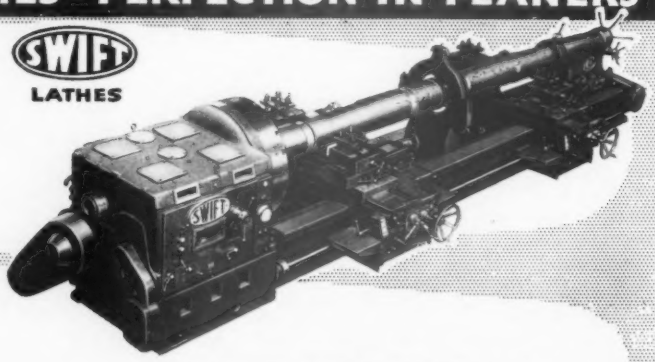

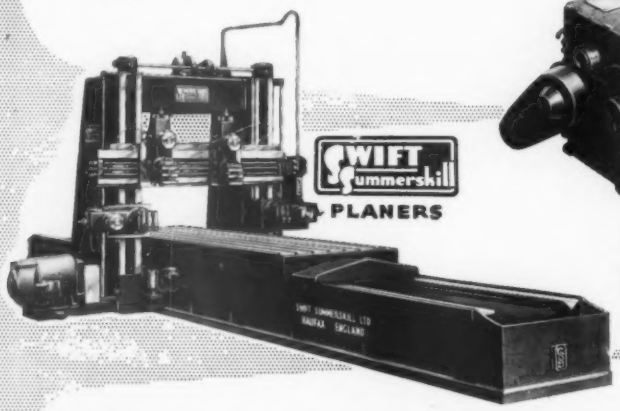

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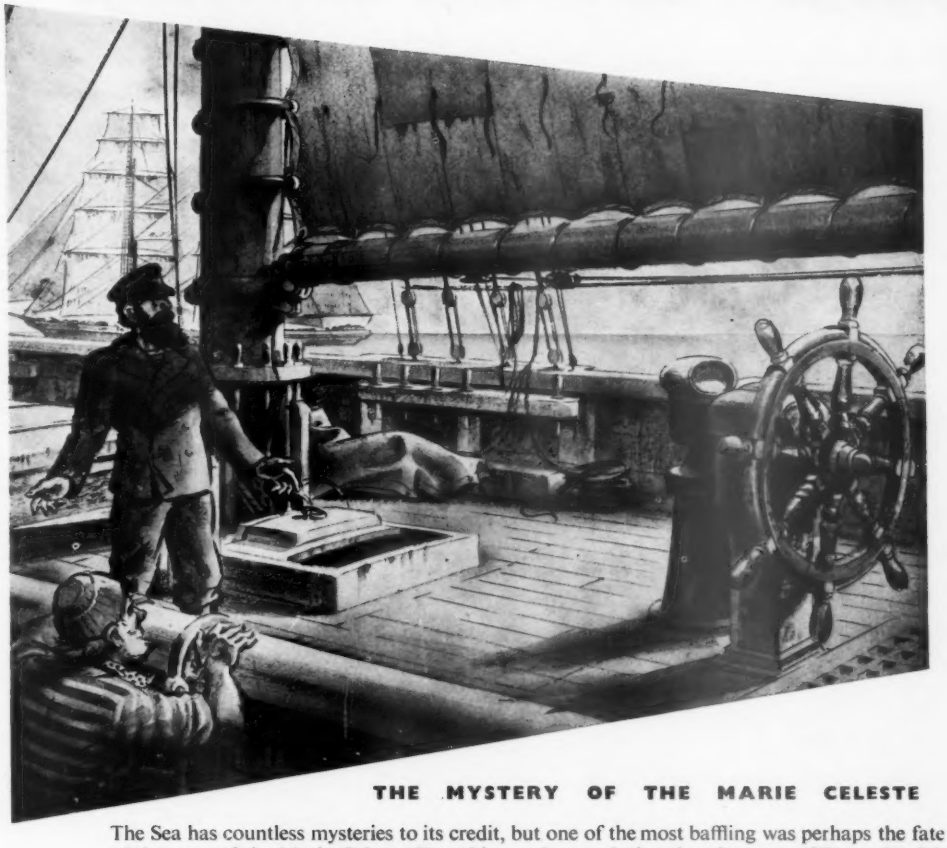

THE MYSTERY OF THE MARIE CELESTE

The Sea has countless mysteries to its credit, but one of the most baffling was perhaps the fate of the crew of the Marie Celeste. Found in a calm sea during the afternoon of December 5th, 1872, the ship was mid-way between the Azores and the coast of Portugal. When Captain Morehouse, commander of the brig Dei Gratia sailing out of Nova Scotia overhauled her, she appeared perfectly normal. Her sails were set and filling to a light northerly breeze and Captain Morehouse recognised her as the ship which he had seen loading in New York, and which had left three days before him. He had had a drink or two with her Master, an old acquaintance of his named Briggs, so it was only natural that he should sail close, and hail the Marie Celeste. Captain Morehouse was surprised at receiving no acknowledgement and fearing something was wrong, sent his Mate Oliver Deveau to investigate. There was no sign of the crew, no sign of violence and the barrels of alcohol in the hold were untouched. Only a hatch was out of place, upside down and a half drawn cutlass with a few drops of blood lay beside it. The galley was in perfect order, a harmonium in the cabin had been played recently and the log had been made up to November 23rd. Seamen's chests were untouched and everything appeared neat and tidy certainly showing no evidence of bad weather. In spite of many theories, it remains to this day one of the world's great unsolved mysteries.

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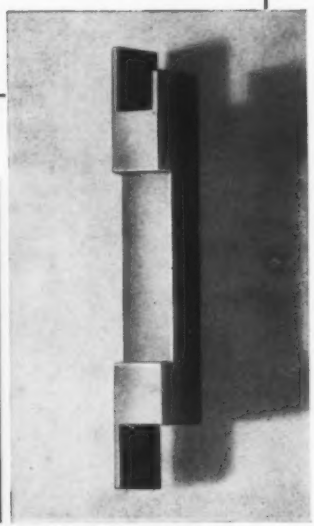

Two views of a cable bridge in 18/8 stainless steel

Trip lever in 18/8 stainless steel

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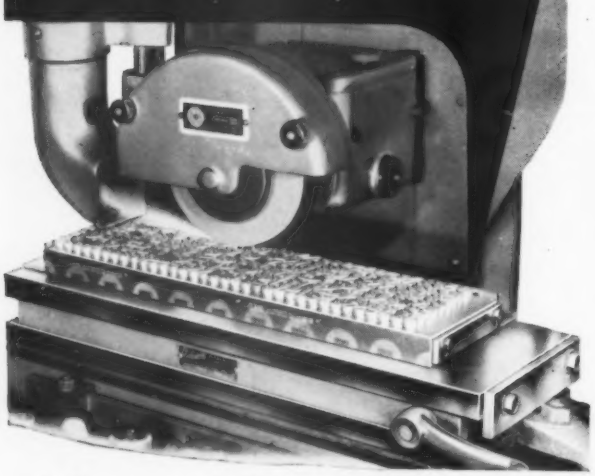

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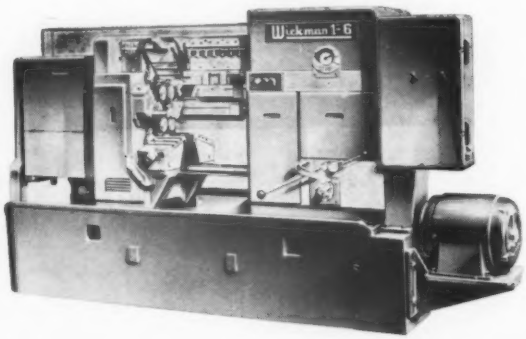

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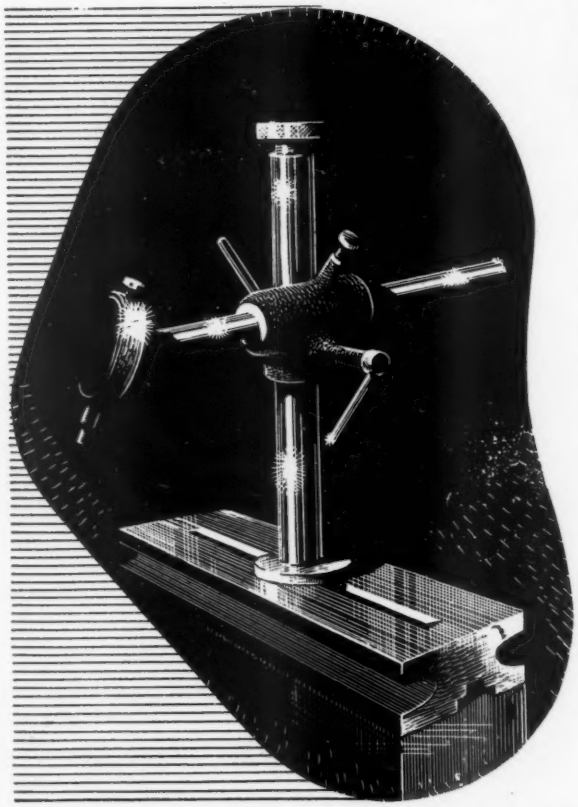

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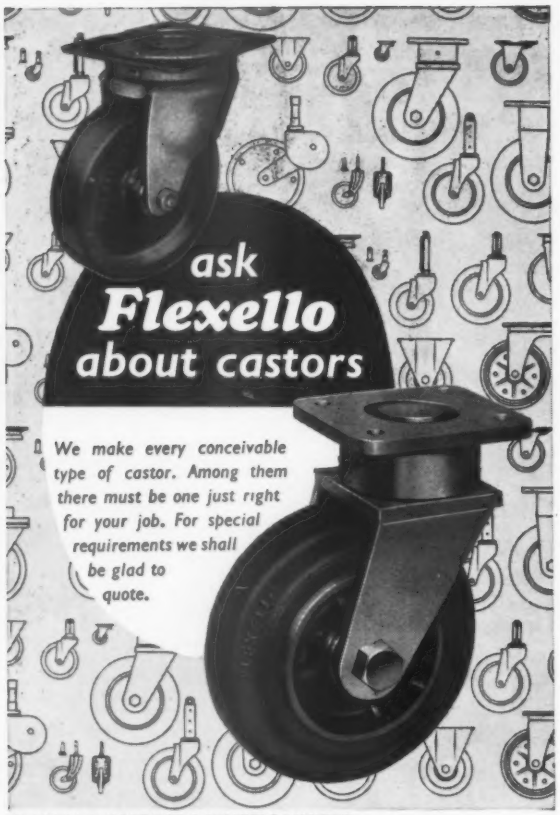
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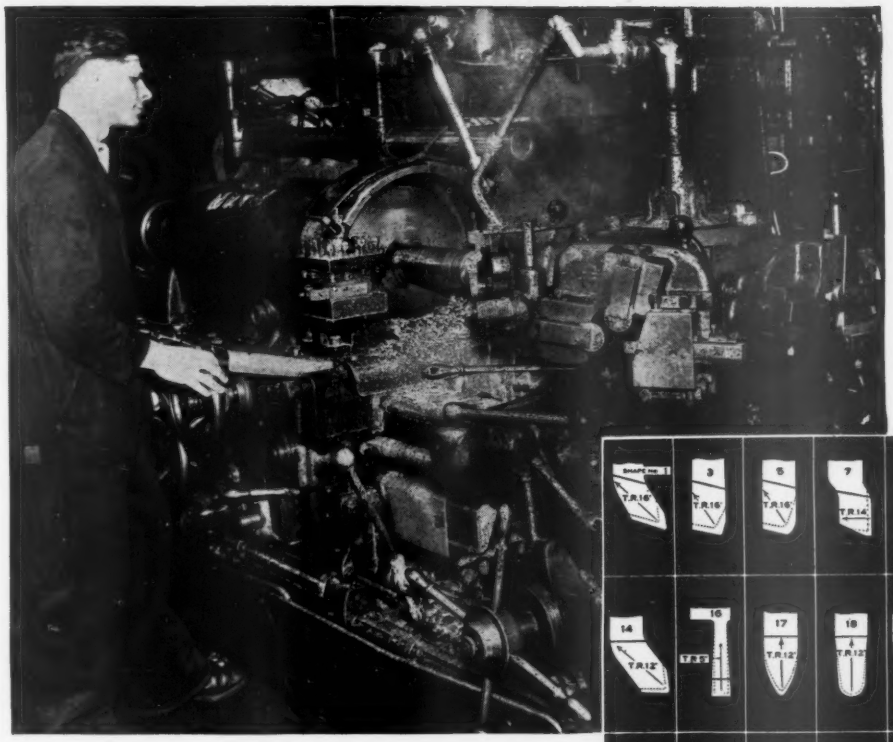

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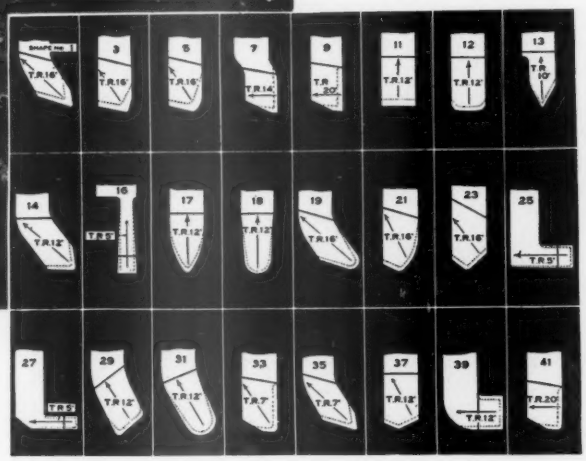

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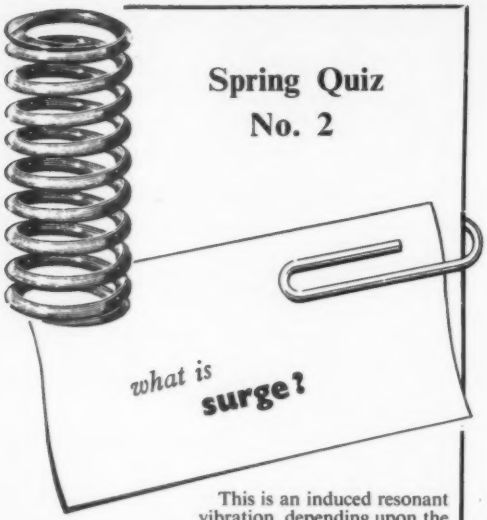

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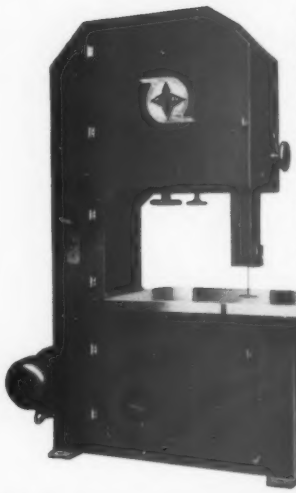

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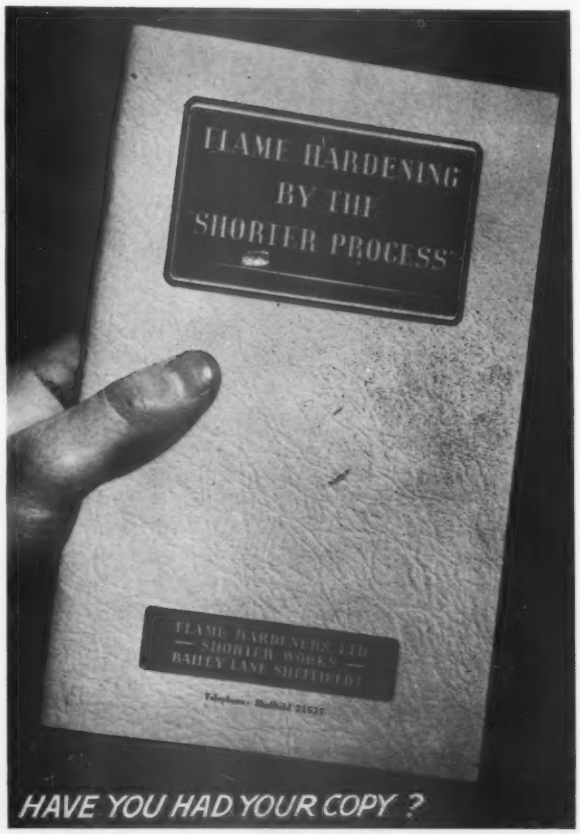

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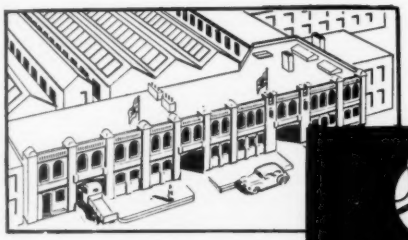

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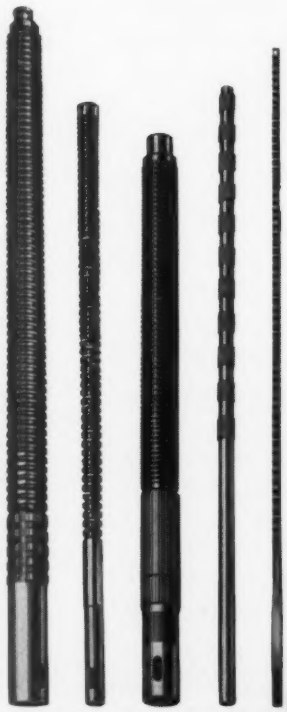

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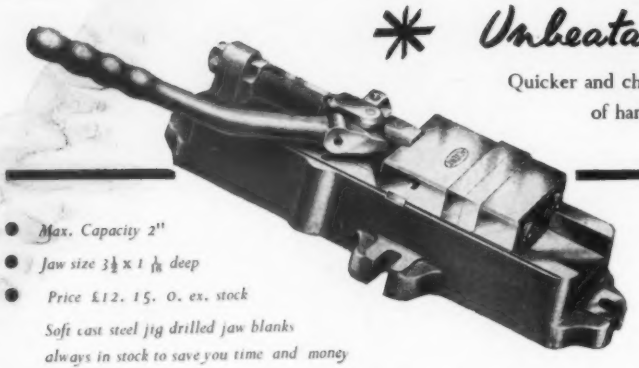

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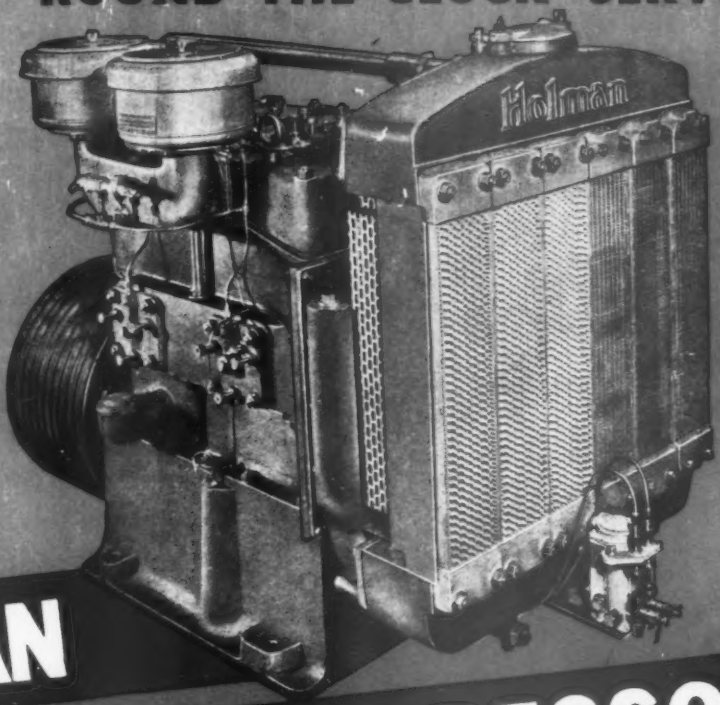

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